MCBU SBED
MANİSA CELAL BAYAR ÜNİVERSİTESİ SAĞLIK BİLİMLERİ ENSTİTÜSÜ DERGİSİ
MANISA CELAL BAYAR UNIVERSITY JOURNAL OF INSTITUTE OF HEALTH SCIENCE
ISSN: 2147-9607

ARAŞTIRMA MAKALESİ
RESEARCH ARTICLE
CBU-SBED, 2025, 12 (1): 102-109

Analysis Of Cervical Transpedicular Screw Placement And Complications Using Pedicle Axis İmaging Techniques İn Patients With Cervical Canal Stenosis

Servikal Kanal Stenozu Olan Hastalarda Pedikül Ekseni Görüntüleme Teknikleri Kullanılarak Servikal Transpediküler Vida Yerleşimi Ve Komplikasyonların Analizi

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Gönderim Tarihi / Received: 17.12.2024
Kabul Tarihi / Accepted: 18.01.2025
DOI: 10.34087/cbusbed.1600808.

Öz

Giriş ve Amaç: Bu çalışmanın amacı, servikal omurga instabilitesi olan hastalarda servikal transpediküler vida (CPS) fiksasyonunun klinik etkinliğini, doğruluğunu ve komplikasyonlarını retrospektif olarak analiz etmektir. Zorlu ancak biyomekanik olarak avantajlı bir teknik olan CPS, diğer fiksasyon yöntemlerine göre daha fazla stabilite sunar. Ancak, uygulaması servikal pedikülün karmaşık anatomisi ve kritik sinir yapılarına yakınlığı nedeniyle sınırlıdır.
Gereç ve Yöntemler: 2015 ve 2022 yılları arasında iki nöroşirürji merkezinde servikal stabilizasyon için CPS uygulanan 28-89 yaş arası 30 hastaya ait veriler retrospektif olarak analiz edildi. Ameliyat öncesi görüntüleme (BT, MRI) kılavuzluğunda cerrahi planlama ve vida yerleşimleri Gertzbein-Robbins ölçeği kullanılarak derecelendirildi. Klinik sonuçlar C2-C7 Cobb açıları ve modifiye edilmiş Japon Ortopedi Derneği (mJOA) skorları kullanılarak değerlendirildi. Nörolojik defisitler, implant başarısızlıkları ve enfeksiyonlar gibi komplikasyonlar belgelendi.
Bulgular: CPS, spinal stabiliteyi iyileştirdi ve ortalama C2-C7 Cobb açısı ameliyat öncesi 3,27°'den ameliyat sonrası 7,72°'ye çıktı. Çoğu hasta (%76,7), önemli nörolojik iyileşmeyle birlikte mJOA skorlarında iyileşme gösterdi. Vida doğruluğu yüksekti ve %43,3'ü A Sınıfı yerleştirme elde etti. Ancak, %30'u sinir yaralanmaları, dura yırtıkları ve implant başarısızlıkları dahil olmak üzere komplikasyonlar yaşadı ve %10'u C Sınıfı yerleştirmelerle ilgiliydi.
Sonuç: CPS fiksasyonu, tekniğin karmaşıklığı nedeniyle komplikasyon riskleri olsa da, servikal omurga instabilitesi için önemli klinik ve radyolojik faydalar sağlar. Vida yerleştirme doğruluğu, sonuçları önemli ölçüde etkiler ve dikkatli ameliyat öncesi planlamanın ve becerinin önemini vurgular. CPS güvenliğini artırmak ve cerrahi teknikleri geliştirmek için daha fazla çalışma önerilmektedir.

Anahtar kelimeler: servikal spinal stenoz, servikal pedikül vidası, mJOA, Gerzbein-Robbins Ölçeği, pedikül ekseni görüntüleme teknikleri

Abstract

Aim; The aim of this study was to retrospectively analyze the clinical efficacy, accuracy, and complications of cervical transpedicular screw (CPS) fixation in patients with cervical spine instability. CPS, a challenging but biomechanically advantageous technique, offers enhanced stability over other fixation methods. However, its application is limited by the complex anatomy of the cervical pedicle and proximity to critical neural structures.

Method; Data were retrospectively analyzed for 30 patients aged 28–89 who underwent CPS for cervical stabilization at two neurosurgery centers between 2015 and 2022. Preoperative imaging (CT, MRI) guided surgical planning, and screw placements were graded using the Gertzbein-Robbins scale. Clinical outcomes were evaluated using C2-C7 Cobb angles and modified Japanese Orthopedic Association (mJOA) scores. Complications such as neurologic deficits, implant failures, and infections were documented.

Results; CPS improved spinal stability, with mean C2-C7 Cobb angle increasing from 3.27° preoperatively to 7.72° postoperatively. Most patients (76.7%) showed improved mJOA scores, with significant neurological recovery. Screw accuracy was high, with 43.3% achieving Grade A placement. However, 30% experienced complications, including nerve injuries, dural tears, and implant failures, with 10% related to Grade C placements.

Conclusion; CPS fixation provides substantial clinical and radiological benefits for cervical spine instability, albeit with risks of complications due to the technique's complexity. Screw placement accuracy significantly impacts outcomes, underscoring the importance of careful preoperative planning and skill. Further studies are recommended to enhance CPS safety and refine surgical techniques.

Keywords: cervical spinal stenosis, cervical pedicle screw, mJOA, Gerzbein-Robbins Scale, pedicle axis imaging techniques

1. Introduction

Cervical transpedicular screw (CPS) fixation is a highly effective yet technically demanding procedure used primarily for stabilizing cervical spinal instability due to a variety of pathologies including degenerative conditions, traumatic injury, and deformities. Since its introduction, CPS has shown biomechanical advantages over other fixation methods, providing greater stability, reduced implant loosening, and allowing for shorter constructs, which contribute to improved clinical outcomes in patients with cervical spinal pathologies. Abumi et al. [1] first described the concept of pedicle screws in cervical stabilization, but high complication rates have been reported due to the pedicle anatomy and its proximity to neural tissues and vertebral foramen[2]. According to earlier anatomical research, the use of pedicle screws for cervical spine stabilization is restricted by the small length of the middle cervical pedicles, the significant obliquity of the cervical pedicle axis, and unique variations in cervical pedicle size[3]. Therefore, cervical lateral mass screwing and laminoplasty procedures have become popular in posterior cervical approaches[4]. However, these techniques do not always provide effective and adequate stabilization and reconstruction in all cases. Therefore, cervical pedicle screwing may become mandatory in some cases. Complication rates may increase due to the difficulty of the technique and the length of the learning curve[5]. Although some centers try to apply the technique with spinal navigation, free hand screw delivery is common due to the lack of the device in every center, difficulties in application, and inaccurate results. With the advancement of anatomical studies and techniques, the effective screw placement rate can be as high as 87.5%[6]. To classify the accuracy of pedicle screw placement, the Gertzbein-Robbins scale is commonly used, providing a standardized measure for evaluating screw positioning and associated risks. This study examines the surgical outcomes, accuracy of CPS placement, and associated complications in a cohort of 30 patients who underwent CPS for cervical spinal stabilization, aiming to contribute to the understanding of factors that influence clinical and radiological outcomes in CPS.

2. Patients and Methods

Data from 30 patients (both male and female), aged 28 to 89 years, with cervical spinal stenosis who were admitted to the neurosurgery unit between 2015 and 2022 were evaluated retrospectively. Our study was approved by Tekirdağ Dr. İsmail Fehmi Cumalıoğlu Şehir Hastanesi Clinical Research Ethics Committee (approval number: 19.04.2024/98). All participants gave informed consent.

2.1 Patient Inclusion Criteria

Patients with diagnosed cervical canal stenosis, those undergoing posterior cervical transpedicular screw fixation, and individuals aged 18–90 years who have undergone preoperative CT assessment were included in the study. Exclusion criteria were as follows: healthy volunteers, cervical canal stenosis based on a history of trauma, patients under 18 years of age, patients who were unable to provide anamnesis and detailed examination/ were unconscious/ were in intensive care unit and patients with insufficient postoperative follow-up data (imaging and neurological status).

2.2 Preoperative Assessment and Surgical Technique

Each patient underwent preoperative CT and MRI imaging of the entire spinal column to assess for additional multilevel instability and injuries. CT scans were used to measure pedicle dimensions, including length, width, and trajectory angles, and to assess bone quality (compact or cancellous) to guide surgical planning. Appropriate screw lengths were determined to ensure they would reach the anterior one-third of the vertebral body when fully tightened.

For the surgical procedure, patients were positioned prone with the head secured. A midline incision was made, and the posterior paravertebral muscles were dissected to expose the facet joints. Pedicle entry points were placed approximately 1–2 mm lateral to the midpoint of the superior articular process.

Bone quality as determined by CT informed the approach to screw insertion. In cases with sclerotic bone, the cortex was perforated with a 1-mm high-speed diamond burr, tapped manually, and drilled at a 25°–45° medial angulation. For cancellous bone, a blunt pedicle probe was used, maintaining the trajectory close to the medial wall of the pedicle, which provides the greatest strength. Screw diameter (average of 3.5 mm) and sagittal trajectory were confirmed with biplanar fluoroscopy, and axial angles were aligned medially according to the pedicle’s natural orientation.

To prevent neural injury, rods were secured to the screws before decompression, and hemostatic materials were placed at the site of screw insertion. For spinal fusion, autografts from the patient's spinous processes or laminae were generally used, while allogenic bone grafts were utilized if decompression was unnecessary.

Also, 5 patients had Anterior cervical discectomy and fusion (ACDF), which is a surgical procedure used to relieve spinal cord or nerve root pressure in the cervical spine by removing a damaged disc. Through an incision in the front of the neck, the problematic disc was removed and replaced it with a bone graft or cage to support fusion between adjacent vertebrae.

2.3 Follow-up

Before discharge, clinical and radiological examinations were conducted during the preoperative and early postoperative phases. Follow-up evaluations were then scheduled every three months, continuing for at least one year after surgery.

Clinical and radiological efficacy assessment

We examined the preoperative C2-C7 cobb angle, early postoperative C2-C7 cobb angle, and late postoperative (1-year) C2-C7 Cobb Angle, as well as early and late postoperative local surgical site angulations. Additionally, preoperative modified Japanese Orthopedic Association (mJOA) scores were evaluated, categorizing patients into mild (mJOA >15), moderate (mJOA 12–14), and severe (mJOA <12) groups based on severity of functional and motor deficiencies.

2.4 Classification of cervical pedicle screw misplacement

To evaluate the accuracy of pedicle screw placement, The Gertzbein-Robbins scale is used. The screw's departure from the desirable intrapedicular trajectory is reflected in the grading system. The following are the grades: An intrapedicular screw in grade A does not penetrate the pedicle's cortical layer; a screw in grade B does so but does not go beyond it laterally by over 2 mm; Screws (arrows) in Grades C and D penetrate less than 4 and 6 mm, respectively, and those in Grade E either do not penetrate the pedicle or breach the cortical layer of the pedicle in any direction by over 6 millimeters at any time throughout their planned intrapedicular course. This scale assigns grades (A to E) based on how much the screw deviates outside the pedicle, with Grade A indicating no breach and Grade E indicating a breach of more than 6 mm.

2.5 Complications

Complications were evaluated as follows: complications directly attributable to the screw, screw malposition, neurologic complications, implant failure and others. Neurologic complications were evaluated by analyzing preoperative, postoperative and follow-up periods. Postoperative infection and vascular complications were evaluated by reviewing the surgery. Instrumentation failure was reviewed using postoperative radiographs (plain radiographs, dynamic radiographs, and cervical CT). Nerve root injury, vertebral artery injury, spinal cord injury, broken screws and loose screws were evaluated.

2.6 Statistical Analysis

The clinical and demographic data were evaluated using descriptive statistics. A normal distribution's metrics are its mean and range. Angulations, preoperative and postoperative mJOA scores were examined using two-tailed paired t-tests. The sign test was used to analyze the Cobb angle shift from preoperative to postoperative. To find statistically and clinically significant factors for assessment in exploratory data analysis, univariate analysis was performed. In the logistic regression analysis for Gertzbein-Robbins B and C screw placements, patients were grouped by age, with 65 years serving as the cutoff, in accordance with the WHO classification for geriatric age. Similarly, operation time was categorized using a cutoff of 4 hours, as this represented the median surgery duration in our study. SPSS version 29 for Mac (IBM Corp. Armonk, NY) was used for all statistical analyses, and p<0.05 was considered statistically significant.

3. Results and Discussion

3.1 Demographic Information

Records of 30 patients who underwent cervical transpedicular screw placement were analyzed. The patients were 13 females and 17 males with a median age of 62 years (28-89). Preoperative MRI signal properties were normal T1/normal T2 in 2 patients (6.7%), normal T1/hyperintense T2 in 26 patients (86.7%), and hyperintense T1/hyperintense T2 in 2 patients (6.7%). The median time to surgery from the onset of symptoms was 15.9 months (range, 2–48).

3.2 Surgical Parameters

The median operative time was 3,9 hours (2-6) and the median hospital stay time was 5,6 days (2-24). Twenty-eight patients received screw placement for cervical spinal stenosis, and 2 were operated on for kyphotic deformity. Besides cervical pedicle placement, 5 patients also had ACDF; 2 patients for level C4-6; 2 patients for level C5-6 and 1 patient for level C5-7. Regular follow-up examinations were performed every 3 months. Results of screw placement at each level are listed in **Table1.**

3.3 Clinical and radiological efficacy assessment

In this study of 30 patients, the average preoperative C2-C7 Cobb angle was 3.27° ± 12.93, which increased to 7.72° ± 9.93 in the early postoperative

3.3 Classification of cervical pedicle screw misplacement

To evaluate the accuracy of pedicle screw placement, The Gertzbein-Robbins scale is used. The number of Grade A patients was 13 (43.3%), Grade B was 9 (30.0%), and Grade C was 8 (26.7%). Factors affecting clinical outcomes in Gertzbein-Robbins B and C patients are listed in Table 2.

Table 1. Results of screw placement at each level

Level	No of Screw	Screw Misplacement (%)	Misplacement Site R/L		Screw Malposition	
			R	L	Lateral	Medial
C2	16	0 (0)	0	0	0	0
C3	44	4(9,1)	1	1	2	0
C4	54	4(7,4)	1	1	2	0
C5	54	12(22,2)	2	1	9	0
C6	46	5(10,8)	1	1	3	0
C7	26	0(0)	0	0	0	0
T1	22	4(18,1)	1	1	2	0
T2	10	2(20)	1	0	0	1
Total Number	272	28(10,2)	7	5	18	1

Table 2. Logistic regression analysis for Gertzbein-Robbins B and C screw placements

Variable	Univariate	
	RR (95% CI)	**p Value**
Age (years) **<65 vs. >65**	0,81 (0,19-3,51)	0,78
Gender **Female vs. Male**	0,70 (0,16-3,05)	0,63
Diagnosis **Cervical Spinal Stenosis vs. Kyphosis**	0,75 (0,04-13,24)	0,84
Level Of Screw Placement		
C2	0,15(0,02-0,97)	**0,04**
C3	0,72 (0,13-3,78)	0,69
C4	2,90 (0,23-36,1)	0,40
C5	2,90 (0,23-36,1)	0,40
C6	4,68 (0,73-29,82)	0,10
C7	2,53 (0,55-11,5)	0,22
T1	1,57 (0,43-7,22)	0,55

T2	1,17 (0,16-8,33)	0,86
Surgery Time (hour) **<4 vs. ≥4**	2,91 (0,54-15,56)	0,21

period and slightly decreased to 6.51° ± 9.86 in the late postoperative period. Early postoperative local angulation was measured at 13.74° ± 11.32, reducing to 11.48° ± 8.24 in the late postoperative phase, indicating some stabilization over time. Regarding the modified Japanese Orthopedic Association (mJOA) scores, preoperatively, 6 patients were classified as mild (mJOA >15), 15 as moderate (mJOA 12–14), and 9 as severe (mJOA <12). Postoperatively, there was significant improvement, with 23 patients categorized as mild, 3 as moderate, and 4 as severe, demonstrating enhanced neurological outcomes following surgery. Pre- and postoperative mJOA comparisons are shown in **Table 3**.

Table 3. Pre- and post-operative, neurological and radiological findings among Gertzbein-Robbins A vs B-

Variable (Mean)	**All Patients ± SD (n:30)**	**Gertzbein-Robbins A ±SD (n:13)**	**Gertzbein-Robbins B-C ±SD (n:17)**	**p value**
Preop C2-C7 Cobb Angle	3,27 ± 12,93	-0,28 ± 12,81	5,98 ± 12,72	0.27
Early Postop C2-C7 Cobb Angle	7,72 ±9,93	5,16 ± 9,32	9,67 ± 10,20	0.12
Late Postop C2-C7 Cobb Angle	6,51 ±9,86	4,42± 10,48	8,11 ± 9,37	0.33
Early Postoperative Local Angulation	13,74 ±11,32	8,23±5,65	17,95±12,83	**0.01**
Late Postop Local Angulation	11,48 ± 8,24	8,47 ± 6,23	13,78 ±9,01	0.11
Preop mJOA Scores **Mild (mJOA >15)** **Moderate (mJOA 12–14)** **Severe (mJOA <12)**	6 15 9	2 8 3	4 7 6	0.83
Postop mJOA Scores **Mild (mJOA >15)** **Moderate (mJOA 12–14)** **Severe (mJOA <12)**	23 3 4	11 2 0	12 1 4	0.27

3.5 Complications

Nine patients (%30) had complications due to surgery. Complications directly attributable to surgery included 5 nerve root injuries (4 C5 palsy, 1 radiculopathy) and 1 vertebral artery injury. Other complications were 3 dural tear, 1 malposition, and 1 shoulder impingement. Three patients with Gertzbein score C had implant failure: The first patient had C4-T2 transpedicular screw placement for cervical spinal stenosis and had radiculopathy after surgery. Second patient with implant failure had C3-C5 screw placement and C5-6 ACDF for cervical spinal stenosis. Third patient had a corpectomy and then C3-T1 screw placement for kyphotic deformity. He had dural tear complications **(Table 2)**.

The most stable kind of cervical instrumentation has been demonstrated to be cervical pedicle screw fixation[2]. However, because the spinal cord, nerve roots, and vertebral arteries are so close together, the procedure is regarded as extremely dangerous. The cervical pedicle's axis is significantly inclined in the transverse plane, and its diameter is lower than that of the thoracolumbar pedicle[7]. According to Roy-Camille, there would be an intolerable danger of harm to the spinal cord, nerve roots, and vertebral arteries if transpedicular screws were inserted in the C3-6 pedicles[8]. Therefore, with the developing technology, navigated systems have come to the forefront. There have been reports of improved screw insertion accuracy using a computer-assisted navigation system[9, 10]. However, the systems are expensive, not available in every hospital, and it may take time to take detailed films and upload them to the system. In addition, navigation does not perform live imaging, which can sometimes lead to incorrect results in screw

placement. Therefore, successful placement of pedicle screws requires accurate definition of the pedicle axis. The accuracy of screw placement will be greatly improved if an accurate entry point coinciding with the correct trajectory angle is identified during surgery. Additionally, even at the same cervical vertebral level, there are significant differences between people in the site of the pedicle entrance, which varies according to each level[11].
Pedicle axis imaging techniques refer to specialized imaging methods used to visualize and assess the pedicle axis, the path through the vertebra's pedicles. Using pedicle axis imaging (often involving CT or fluoroscopic imaging), surgeons can evaluate the alignment and angulation of the pedicle relative to the vertebra. This is especially important in cases of cervical canal stenosis, where the spinal canal is constricted, making accurate screw placement challenging but crucial to avoid complications such as nerve or spinal cord injury[12]. According to a multicenter study conducted in Japan on the difficulties of installing CPS using only free-hand approach, lateral pedicle perforation accounted for 75% (57/76) of all misplaced screws, whereas medial pedicle perforation accounted for only 25% (19/76)[13]. With the help of pedicle axis imaging techniques, we observed lateral pedicle perforation in only 18 screws (10%).

Aside from proper insertion, the results demonstrate favorable improvements in spinal alignment and neurological outcomes following surgery with pedicle axis imaging. The C2-C7 Cobb angle improved from a preoperative mean of 3.27° to 7.72° in the early postoperative phase, stabilizing at 6.51° at the late postoperative follow-up. This suggests that CPS provided effective spinal alignment and stabilization in most of the patients. Additionally, mJOA scores indicated significant neurological improvement, with a substantial increase in patients classified as mild postoperatively (23 patients) compared to preoperative assessments. These findings reinforce the efficacy of CPS in enhancing both alignment and neurological function in patients with cervical spinal stenosis.
Despite these positive outcomes, the procedure carried a notable risk of complications, observed in 30% of our cohort. The most common complications included nerve root injuries like C5 palsy and radiculopathy. According to a review of the literature, pedicle screw misplacement rates varied from 1.1% to 28.8%,6 and in 4% of cases, screw implantation caused nerve root damage (2% permanent and 2% transitory)[14]. Transient neural palsy was discovered in 8% of the 148 patients in a case series by Okuyama et al. but no cases of lasting neurological damage due to pedicle screws were discovered[15]. The pathophysiology of C5 radiculopathy remains poorly understood, with multiple contributing factors hypothesized. Three primary theories have been proposed: (1) direct intraoperative neural injury, (2) "tethering" of the relatively short C5 nerve root, and (3) spinal cord ischemia and reperfusion injury[16]. In our study, although no direct intraoperative injury to the C5 nerve root was observed, these alternative mechanisms may explain the development of palsy in four of our patients.

Vertebral artery injury, though seen only in 1 patient, is a severe complication with potentially high morbidity. There is a greater chance of vertebral artery damage when C1–C2 transarticular or C2 pedicle screws are inserted[17]. Given the possibility of vertebral artery damage at C2, it has been proposed that C2 pedicle screw placement in conjunction with C1 lateral mass screw placement is intrinsically safer than C1-C2 transarticular screw fixation because the medially directed trajectory of the C2 pedicle screw pulls the screw away from the vertebral artery, which is typically lateral to the screw[18]. However, in our study, vertebral artery injury was observed during the insertion of screws at the C3 level. This complication may be attributed to anatomical alterations commonly seen in patients with cervical spinal stenosis. In patients with Gertzbein-Robbins grades B and C, the risk of complications appeared to increase, with implant failure observed in three patients with grade C score, suggesting that misalignment or mispositioning of screws is an influential factor in adverse outcomes. This reinforces the need for precise pedicle targeting, as suboptimal placement can compromise the stability of the construct and heighten the risk of neurological or vascular complications.

In this study, we aimed to contribute to the literature by presenting our series of 272 screws. We believe that the best way to perform a surgery safely and accurately without a high complication rate can be achieved by having deep knowledge about patient's cervical anatomy. Preoperative pedicle thickness, angles, vertebral foramen should be meticulously evaluated in 3D CT images. We believe that the cervical pedicles should be clearly visualized with right and left oblique views and studied preoperatively, especially since the lateral view of the scope is not fully visualized due to the patient's position and shoulders[19].

4.1 Limitations

This study has several limitations. First, the sample size of 30 patients is relatively small, which may limit the generalizability of the findings to broader populations. Additionally, the study's retrospective design may introduce selection and recall biases, affecting the accuracy of recorded outcomes and complications. The follow-up period, while sufficient for early outcomes, may not capture long-term complications or the durability of surgical results. Furthermore, variations in surgical technique and skill among surgeons could influence outcomes but were not controlled for in this analysis. Finally, while the Gertzbein-Robbins scale was used to assess screw placement accuracy, more advanced imaging techniques, which may provide greater precision, were not evaluated.

4.2 Suggestions for future research

Future research should explore advanced navigation systems with real-time imaging, patient-specific 3D modeling, and risk stratification for high-risk patients to enhance CPS placement accuracy and safety. Long-term outcome studies and cost-effectiveness analyses are also recommended to assess the durability of CPS benefits and the feasibility of widespread technological adoption. Additionally, comparative studies on alternative screw placement techniques and angulation protocols could help refine best practices for optimal outcomes.

4. Conclusion

Cervical transpedicular screw placement effectively stabilizes the spine and improves neurological outcomes, as shown by significant postoperative improvements in alignment and mJOA scores. However, the procedure carries a 30% complication rate, primarily involving nerve injuries and dural tears, with increased risks associated with lower accuracy grades on the Gertzbein-Robbins scale. These results highlight the importance of precise screw placement to minimize complications. Advances in imaging and navigation could further improve safety and efficacy, enhancing both stability and patient recovery in CPS procedures.

6. Referances

1. Abumi, K., *Cervical Spondylotic Myelopathy: Posterior Decompression and Pedicle Screw Fixation.* European Spine Journal, 2015. **24**(S2): p. 186-196.
2. Yukawa, Y., F. Kato, K. Ito, Y. Horie, T. Hida, H. Nakashima, et al., *Placement and Complications of Cervical Pedicle Screws in 144 Cervical Trauma Patients Using Pedicle Axis View Techniques by Fluoroscope.* European Spine Journal, 2009. **18**(9): p. 1293-1299.
3. Sun, M., Q. Wang, X. Zhang, R. Zhao, K. Guo, and F. Yuan, *Development and Biomechanical Analysis of a New Anterior Cervical Pedicle Screw Fixation System.* 2021.
4. Liu, G., L. Hu, Y. Gu, and W. Ma, *Outcomes of Combined Open-Door Laminoplasty With Bilateral Lateral Mass Screw Fixation for Traumatic Unstable Multilevel Cervical Stenosis: A Retrospective Case Study.* 2022.
5. Li, K., Y. Han, and J. Lan, *Freehand Regional Techniques for Subaxial Cervical Pedicle Screw Placement.* The International Journal of Spine Surgery, 2022. **16**(5): p. 863-867.
6. Liu, B., X. Li, X. Shen, G. Wang, and Y. Chen, *The "Slide Technique"—a Novel Free-Hand Method of Subaxial Cervical Pedicle Screw Placement.* BMC Musculoskeletal Disorders, 2020. **21**(1).
7. Yoon, S.D., J.Y. Lee, I.S. Lee, S.H. Moon, B.M. Cho, S.H. Park, et al., *Cervical Pedicle Screw Placement in Sawbone Models and Unstable Cervical Traumatic Lesions by Using Para-Articular Mini-Laminotomy: A Novice Neurosurgeon's Experience.* Korean Journal of Neurotrauma, 2013. **9**(2): p. 106.
8. Barrey, C., P. Mertens, J. Jund, F. Cotton, and G. Perrin, *Quantitative anatomic evaluation of cervical lateral mass fixation with a comparison of the Roy-Camille and the Magerl screw techniques.* Spine (Phila Pa 1976), 2005. **30**(6): p. E140-7.
9. Vardiman, A.B., D.J. Wallace, N.R. Crawford, J.R. Riggleman, L.A. Ahrendtsen, and C.G.T. Ledonio, *Pedicle Screw Accuracy in Clinical Utilization of Minimally Invasive Navigated Robot-Assisted Spine Surgery.* Journal of Robotic Surgery, 2019. **14**(3): p. 409-413.
10. Tian, N., Q.-S. Huang, P. Zhou, Y. Zhou, R.-K. Wu, Y. Lou, et al., *Pedicle Screw Insertion Accuracy With Different Assisted Methods: A Systematic Review and Meta-Analysis of Comparative Studies.* European Spine Journal, 2010. **20**(6): p. 846-859.
11. Lee, S., J. Seo, M.K. Lee, S.R. Jeon, S.W. Roh, S.C. Rhim, et al., *Widening of the Safe Trajectory Range During Subaxial Cervical Pedicle Screw Placement: Advantages of a Curved Pedicle Probe and Laterally Located Starting Point Without Creating a Funnel-Shaped Hole.* Journal of Neurosurgery Spine, 2017. **27**(2): p. 150-157.
12. Liu, G., L. Hu, W. Ma, D. Xu, Y. Gu, Y. Hu, et al., *Clinical Outcomes of Open-Door Laminoplasty Combined with Bilateral Lateral Mass Screw Fixation for Multi-Level Cervical Spinal Stenosis with Traumatic Cervical Instability and Spinal Cord Injury: A Retrospective Study.* Orthop Surg, 2023. **15**(7): p. 1781-1789.
13. Nakashima, H., Y. Yukawa, S. Imagama, T. Kanemura, M. Kamiya, M. Yanase, et al., *Complications of cervical pedicle screw fixation for nontraumatic lesions: a multicenter study of 84 patients.* J Neurosurg Spine, 2012. **16**(3): p. 238-47.
14. Hadjipavlou, A., P. Enker, P. Dupuis, S. Katzman, and J. Silver, *The causes of failure of lumbar transpedicular spinal instrumentation and fusion: a prospective study.* Int Orthop, 1996. **20**(1): p. 35-42.
15. Okuyama, K., E. Abe, T. Suzuki, Y. Tamura, M. Chiba, and K. Sato, *Posterior lumbar interbody fusion: a retrospective study of complications after facet joint excision and pedicle screw fixation in 148 cases.* Acta Orthop Scand, 1999. **70**(4): p. 329-34.
16. Sarkar, S., B.R. Nair, and V. Rajshekhar, *Complications Following Central Corpectomy in 468 Consecutive Patients With Degenerative Cervical Spine Disease.* Neurosurgical Focus, 2016. **40**(6): p. E10.
17. Yeom, J.S., J.M. Buchowski, H.-J. Kim, B.S. Chang, C.-K. Lee, and K.D. Riew, *Risk of Vertebral Artery Injury: Comparison Between C1–C2 Transarticular and C2 Pedicle Screws.* The Spine Journal, 2013. **13**(7): p. 775-785.
18. Chen, J.F., C.T. Wu, S.C. Lee, and S.T. Lee, *Posterior atlantoaxial transpedicular screw and plate fixation. Technical note.* J Neurosurg Spine, 2005. **2**(3): p. 386-92.
19. Stolzenberg, D., R. Pheifer, J. Armstrong, G.W. Young, J. Gehret, J.I. Simon, et al., *Improving Fluoroscopic Visualization for Lower Cervical Medial Branch Blocks With a Modified Swimmer's View: A Technical Report.* Pain Physician, 2018. **1**(21;1): p. 303-308.