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SUBAXIAL CERVICAL PEDICLE SCREWS WITHOUT NAVIGATION: IS IT SAFE AND FEASIBLE?

PARAFUSOS PEDICULARES NA COLUNA CERVICAL SUBAXIAL SEM NAVEGAÇÃO: É SEGURO E VIÁVEL?

TORNILLOS PEDICULARES EN LA COLUMNA CERVICAL SUBAXIAL SIN NAVEGACIÓN: ¿ES SEGURO Y VIABLE?

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ABSTRACT

Objective: The application of pedicle screws in the subaxial cervical spine is a highly complex technique, but with significant biomechanical advantages. Despite the potential complications involved, its use has increased. This study aims to evaluate the clinical and radiological outcomes, as well as the occurrence of potential complications associated with such screws. Methods: A total of 102 subaxial pedicle screws were assessed in the treatment of cervical pathologies (19 patients) between 2005 and 2021, using hybrid instrumentation concepts combining the original technique of Abumi, the Funnel Technique, and Pedicle Axis View, without the use of 3D navigation. Clinical evaluation was performed postoperatively to identify signs and symptoms related to spinal cord injury, cervical nerve root damage, and vertebral artery involvement. The classification of screw positioning was performed according to the method proposed by Neo et al. Results: 81.37% of the screws were well-positioned with no deviation, and only 1.96% had a Grade 3 deviation according to Neo's classification. The level most prone to critical deviations (Grades 2 and 3) was C3, while C6 showed the best accuracy (96.66%). Incorrect positioning was most often lateral (68.42% of cases with deviation). No screws were classified as Grade 3 for medial deviation. There were no vascular complications related to the vertebral artery. Conclusion: Despite being technically demanding, the use of pedicle screws in the subaxial cervical spine proved to be safe, with a low rate of malpositioning in postoperative CT scans and few significant clinical complications. ***Level of Evidence IV; Case Series.***

Keywords: Cervical Vertebrae; Spinal Fusion; Prostheses and Implants.

RESUMO

Objetivo: A aplicação de parafusos pediculares na coluna cervical subaxial é uma técnica de alta complexidade, porém com vantagem biomecânica significativa. A despeito das potenciais complicações envolvidas, seu uso tem aumentado. O objetivo deste estudo é avaliar os resultados clínicos e radiológicos bem como a ocorrência de possíveis complicações de tais parafusos. Métodos: Foram avaliados 102 parafusos pediculares subaxiais no tratamento de patologias cervicais (19 pacientes), no período entre 2005 e 2021, em que foram utilizados conceitos híbridos de instrumentação entre a técnica original de Abumi, a Funnel Technique e Pedicle Axis View, sem o uso de navegação tri-dimensional. A avaliação clínica foi feita no período pós-operatório a procura de sinais e sintomas relacionados à lesão medular, de raízes nervosas cervicais e da artéria vertebral. A classificação do posicionamento dos parafusos foi realizada de acordo com a proposta por Neo et al. Resultados: 81,37% dos parafusos não apresentavam nenhum desvio e apenas 1,96% tinham desvio grau 3 de Neo. O nível mais sujeito a desvios críticos (graus 2 e 3) foi C3, sendo C6 o nível com melhor acurácia (96,66%). O posicionamento incorreto foi mais frequentemente lateral (68,42% dos casos com desvio). Não houve nenhum parafuso classificado como Grau 3 para desvio medial. Não houve complicações vasculares relativas à artéria vertebral. Conclusão: Apesar de tecnicamente exigente, a utilização de parafusos pediculares na coluna cervical subaxial se mostrou segura, com baixa taxa de mau posicionamento na análise tomográfica pós-operatória e complicações clínicas relevantes. ***Nível de Evidência IV; Série de Casos.***

Descritores: *Vértebras Cervicais; Fusão Vertebral; Próteses e Implantes.*

RESUMEN

Objetivo: La aplicación de tornillos pediculares en la columna cervical subaxial es una técnica de alta complejidad, pero con ventajas biomecánicas significativas. A pesar de las posibles complicaciones involucradas, su uso ha aumentado. El objetivo de este estudio es evaluar los resultados clínicos y radiológicos, así como la ocurrencia de posibles complicaciones asociadas con estos tornillos. Métodos: Se evaluaron 102 tornillos pediculares subaxiales en el tratamiento de patologías cervicales (19 pacientes) entre 2005 y 2021, utilizando conceptos híbridos de instrumentación que combinan la técnica original de Abumi, la Funnel Technique y Pedicle Axis View, sin el uso de navegación tridimensional. La evaluación clínica se realizó en el período postoperatorio buscando signos y síntomas relacionados con lesiones de la médula espinal, raíces nerviosas cervicales y la arteria vertebral. La clasificación de la posición de los tornillos se realizó según lo propuesto por Neo et al. Resultados: El 81,37% de los tornillos no presentaron desviaciones y solo el 1,96% tuvieron una desviación grado 3 según la

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clasificación de Neo. El nivel más propenso a desviaciones críticas (grados 2 y 3) fue C3, siendo C6 el nivel con mejor precisión (96,66%). El posicionamiento incorrecto fue más frecuente en dirección lateral (68,42% de los casos con desviación). No hubo tornillos clasificados como Grado 3 para desviación medial. No se presentaron complicaciones vasculares relacionadas con la arteria vertebral. Conclusión: A pesar de ser técnicamente exigente, el uso de tornillos pediculares en la columna cervical subaxial demostró ser seguro, con una baja tasa de mala posición en las tomografías postoperatorias y pocas complicaciones clínicas relevantes. ***Nivel de Evidencia IV; Serie de Casos.***

Descriptores: *Vértebras Cervicales; Fusión Vertebral; Prótesis e Implantes.*

INTRODUCTION

Modern cervical spine surgery uses instrumentation techniques to provide greater stability and reduced postoperative immobilization times compared to older treatment methods. In 1964, Roy-Camille described the use of lateral mass screws, with several other techniques being described since then.[1]

The first subaxial cervical pedicle screw insert description was made by Abumi et al.[2] Later, cadaveric studies demonstrated greater pull-out strength and stability of pedicle screws when compared to lateral mass ones.[3,4]

Currently, several other techniques for subaxial pedicle screws are available, such as axial pedicle view,[5] funnel technique,[6] percutaneous placement, and many others. Each of these variations has its idiosyncrasies regarding technical difficulty, execution time, required hardware, and radiation exposure.

This study aims to evaluate the clinical and radiological outcomes, as well as the safety of applying pedicle screws in the subaxial cervical spine by observing complications in a series of cases.

METHODS

Study design

A retrospective cohort study from a single referral center involving 19 patients who underwent surgical treatment for cervical spine pathologies between 2005 and 2021. This study was approved by the local ethics committee (39417220.5.0000.5273), and patients or their legal guardians provided consent for the anonymized use of their images.

Study participants

All patients who underwent cervical fixation with pedicle screws in the C3, C4, C5, and C6 vertebrae between 2005 and 2021 were included. Patients selected for this technique had favorable pedicle morphology demonstrated by preoperative CT scans, with a minimum pedicle diameter of 35mm on the axial image. Pedicle screws placed in C2 and C7, as well as lateral mass or laminar screws, were excluded from the evaluation.

Demographic data, surgical details, and complications were obtained from medical records, with the authors directly involved in the surgical procedures and postoperative follow-up. Data on age, sex, diagnosis, Frankel's neurological classification, surgical procedure, use of neuromonitoring, intraoperative blood transfusion, surgical time, hospitalization time, and complications were collected.

Clinical assessment

All patients were followed up in the immediate postoperative period and during subsequent outpatient visits by at least one of the authors, being examined for neurological symptoms related to the vertebral artery territory, sensory and motor changes of the cervical roots, signs of spinal cord involvement or worsening of the pre-existing condition, wound dehiscence, or infection. All adverse intra- or postoperative events occurring within 6 weeks were considered complications and were correlated with the application of subaxial cervical pedicle screws.

Radiographic assessment

Postoperative CT scans were performed in all patients using a Phillips Brilliance CT scanner (64 channels) with a 1mm slice protocol. Pedicle screw positioning was classified jointly by the authors, evaluating axial CT images along the screw axis. The classification proposed by Neo et al.[7] was used, in which Grade 0 corresponds to a screw fully within the pedicle with no deviation; Grade 1, deviation of up to 2mm (or less than 50% of the screw diameter); Grade 2, deviation greater than 2mm but less than 4mm; Grade 3, deviation greater than 4mm (complete deviation). Lateral deviation is identified by the (+) sign, and medial deviation by the (-) sign. Examples of lateral screw positioning can be observed in Figure 1.

Surgical technique

The surgical technique used combined elements of Abumi's[2] original technique, the Funnel Technique,[5] and the Pedicle Axis View,[6] without the use of 3D navigation, which was the standard technique for the authors.[8] The procedure was initiated with the patient in the prone position under general anesthesia, using intraoperative neuromonitoring in most cases. Endotracheal tubes and radiolucent gauze in the oral cavity were used for better visualization of the pedicles in fluoroscopy. After positioning, the

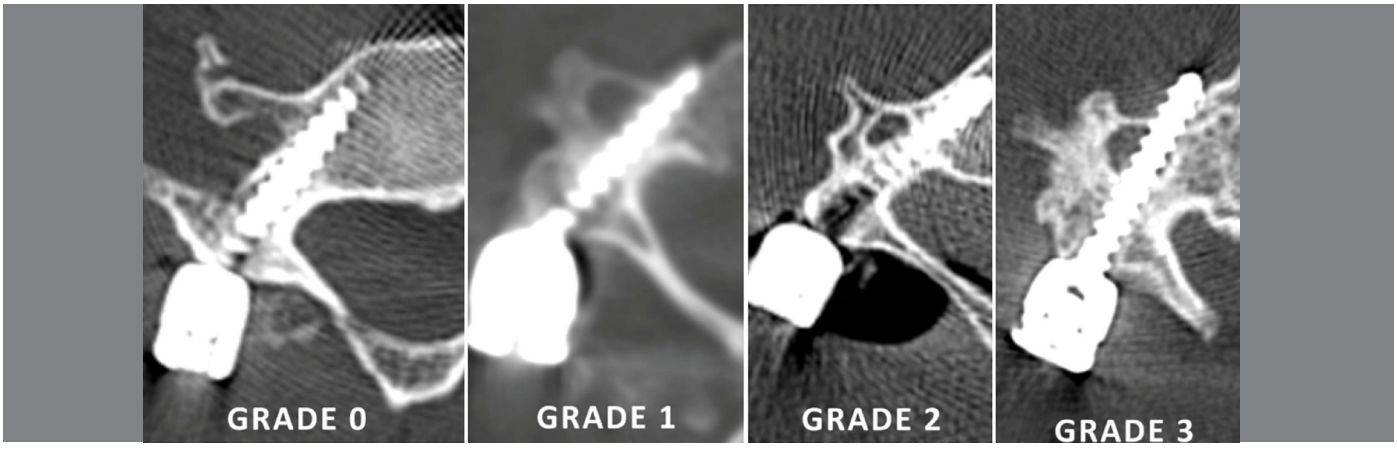

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Figure 1. Neo et al classification, presenting Grade 0 to 3. Grade 0 screw fully within the pedicle; Grade 1 deviation up to 2mm; Grade 2 deviation greater than 2mm but less than 4mm; Grade 3 deviation greater than 4mm. Lateral deviation is identified by the (+) sign and medial deviation by the (-) sign.

anterior-posterior (AP), lateral, and axial pedicle images were checked. Once satisfactory images were obtained and fluoroscopy marks were made, the procedure began with a standard posterior cervical approach, subperiosteal dissection, and exposure of the cervical spine's lateral limits. The initial entry point was the one described by Abumi,[2] slightly lateral to the articular mass, near the posterior margin of the superior articular surface. The cortex was reamed using a high-speed drill or with Kerrison and curettes. A funnel-shaped hole was created, which is crucial to provide the surgeon with the angle needed to contact the medial pedicle cortex. After this step, a probe was used and confirmed with fluoroscopy in the three aforementioned views. Once confirmed by imaging, the probe was carefully advanced to avoid cortical perforation, especially laterally. Fluoroscopic images were repeated, and the hole was explored with a palpation probe. If the tactile response was satisfactory, the screw placement was continued.

Statistics

Statistical analysis was performed using Jamovi version 2.6.26. The Chi-square test was used to compare screw positioning (deviated vs. non-deviated) in each vertebra with the occurrence of deviations and complications. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

A total of 102 subaxial pedicle screws were evaluated in the treatment of cervical pathologies in 19 patients, 14 males and 5 females, aged between 16–76 years (mean = 55.26). The initial diagnosis was spondylotic myelopathy in 9 patients, cervical trauma in 8, and tumor pathologies in 2 patients. The mean surgical time was 289.21 minutes (range 60–430), with a mean hospitalization time of 33.89 days (range 5–188). Patient and complication data are summarized in Table 1.

The overall complication rate was 26.31%, with 28.57% being intraoperative and 71.43% postoperative. Considering only complications directly related to instrumentation, there were two occurrences. One patient presented with radicular neurological impairment corresponding to improper positioning – grade 2 medial, and required reoperation. One patient experienced paresthesia that improved without the need for reoperation. Two patients died of late complications: one from ischemic stroke (territory of the carotid artery) on the seventh postoperative day and another from pneumonia after 96 days. No vascular complications related to the vertebral artery were reported. Two patients had superficial wound infections.

It was found that 81.37% of the screws had no deviation, and only 1.96% had a Grade 3 deviation. The level most prone to critical deviations (Grades 2 and 3) was C3 (18.18%), while C6 showed the best accuracy, with 96.66% of screws showing no cortical perforation. Incorrect positioning was more frequently lateral, occurring in 68.42% of the cases with deviation. No screws were classified as Grade 3 for medial deviation. (Tables 2 and 3)

Regarding deviations in general, they occurred more frequently at C3 and C4 than at C5 and C6, with statistical significance (Table 4). Despite this, the safety of freehand instrumentation is evident, as there was no significant correlation between the instrumented level, deviation occurrence, and the onset of complications. (Tables 5 and 6)

DISCUSSION

Proper screw insertion requires precise identification of the entry point in alignment with the trajectory angle. Failure in either of these steps results in compromised positioning.[9] Subaxial pedicle

Table 2. Screw Placement according to Neo.

	-3	-2	-1	0	+1	+2	+3	Total
C3	0	2	0	15	3	1	1	22
C4	0	0	2	16	5	1	0	24
C5	0	0	1	23	1	0	1	26
C6	0	1	0	29	0	0	0	30
Total	0	3	3	83	9	2	2	102

Table 3. Percentage Analysis of Screw.

	No deviation	**Grade 1**	**Critical deviation (2 + 3)**
C3	68.18%	13.64%	18.18%
C4	66.68%	29.16%	4.16%
C5	88.46%	7.69%	3.85%
C6	96.66%	0%	3.34%
Total	81.37%	11.76%	6.87%

Table 1. Demographic and Clinical.

Id	**Age**	**Sex**	**Diagnostic**	**Neo classification of each screw**								**Transfusion**	**Time (min)**	**Frankel**	**Complication**	**Hospitalization (days)**
				C3 - l	**C3 - r**	**C4 - l**	**C4 - r**	**C5 - l**	**C5 - r**	**C6 - l**	**C6 - d**					
1	76	M	Myelopathy	0	0	-1	0	0	0	0	0	0	240	E	Superficial wound infection	13
2	29	M	Trauma	-	-	-	-	0	0	0	0	0	195	E	No	9
3	47	F	Trauma	-	-	-	-	0	0	0	0	3	270	A	No	13
4	41	F	Trauma	-	-	-	-	0	0	0	0	0	190	E	No	8
5	16	M	Trauma	1	0	0	2	0	0	0	0	0	240	C	No	16
6	63	M	Myelopathy	-	-	0	0		-1	0	-2	0	200	D	No	5
7	65	M	Myelopathy	-	0	-	0	0	0	0	0	0	330	D	Paresthesia	11
8	61	F	Myelopathy	-2	0	0	0	0	0	0	0	0	340	D	No	8
9	47	M	Trauma	0	-	-	-	-	-	-	-	0	60	C	No	24
10	58	F	Tumor	-	-	0	1	-	-	-	-	0	270	E	No	13
11	59	M	Trauma	0	0	0	1	0	0	0	0	0	360	C	No	35
12	59	M	Trauma	0	0	0	0	0	0	0	0	1	240	B	No	188
13	63	M	Myelopathy	0	0	-1	0	0	0	0	0	0	390	E	No	7
14	61	M	Myelopathy	2	3	1	1	0	0	0	0	0	330	E	Right upper limb deficit (grade 3)	43
15	72	M	Myelopathy	0	-2	1	0	-	0	0	0	2	390	C	Death	9
16	62	F	Myelopathy	-	1	-	0	-	-	-	0	0	380	C	Wound infection / pneumonia / death	96
17	65	M	Myelopathy	-	0	0	0	-	-	0	0	1	360	D	No	22
18	59	M	Tumor	-	-	-	-	-	-	-	0	5	430	A	No	108
19	47	M	Myelopathy	0	1	-	-	3	1	-	-	1	280	C	No	16

Table 4. Contingency Table: Deviation x Vertebra.

	Deviation		
Vertebra	**Yes**	**No**	**Total**
c3	7	15	22
C4	8	16	24
C5	3	23	26
C6	1	29	30
Total	19	83	102

χ^2 Tests			
	Value	**df**	**p**
χ^2	11.4	3	0.010
Fisher's exact test			0.006
N	102		

Table 5. Contingency Table: Complication x Deviation.

	Complication		
Deviation	**Yes**	**No**	**Total**
Yes	8	11	19
No	24	59	83
Total	32	70	102

χ^2 Tests			
	Value	**df**	**P**
χ^2	1.25	1	0.264
N	102		

instrumentation is a surgical procedure with a long learning curve, with accuracy rates varying from 16.8% to 97% in the literature.[10] Since the original description in 1994(2), many techniques have been published for this purpose.[9]

Due to the anatomical proximity of the cervical subaxial pedicles to important neurovascular structures, major complications may result from improper screw placement. Complications like neurovascular injury (the most common), indirect nerve root injury due to foraminal stenosis, loosening or pull-out, and loss of reduction are possible.[10]

Most perforations occur laterally;[11] however, vertebral arterial injuries are rare,[12,13] likely because the artery does not occupy the entire foramen,[14] and most perforations are of a smaller degree.[13,15]

Injuries to the dural sac and spinal cord may occur, although perforations of the medial cortex are less frequent. Radicular involvement may happen from a screw misplacement, with a higher risk when it is directed cranially. Excessive reduction of spondylolisthesis or increased tension on the spinal cord/nerve roots after deformity correction may also lead to an iatrogenic foraminal stenosis.[11]

Table 6. Contingency Table: Complication x Vertebra.

	Complication		
Vertebra	**Yes**	**No**	**Total**
C3	8	14	22
C4	8	16	24
C5	7	19	26
C6	9	21	30
Total	32	70	102

χ^2 Tests			
	Value	**Df**	**p**
χ^2	0.563	3	0.905
Fisher's exact test			0.925
N	102		

Neo et al.[7] in 2005, evaluated 18 patients with a total of 88 screws inserted between C2–C6 using the Abumi technique. In their study, the deviation rate was 29%, with 84% being lateral and 16% medial. 15% of the screws had critical deviations (Grades 2 and 3). In our series, we found a deviation rate of 18.63%, with 6.87% critical deviations. As in Neo's study, deviations were more frequently lateral (68.42%) than medial (31.58%). This may be attributed to the use of a larger funnel hole and fluoroscopic control in three different views.[8] Advantages of this technique include the ability to reproduce it without the need for specific materials or navigation.

In 2014, Uehara et al.[13] studied a series of 129 patients with 579 pedicle screws inserted at C2–C7 using navigation, and found a higher incidence of deviations at C4 (31.5% and 13%). In our study, C4 showed the highest incidence of deviations (33.33%), but critical deviations were more frequent at C3 (18.2%). Even with navigation, Uehara et al. had 20% of critical deviation, whereas our study had only 6.87% (this may have occurred due to the sample size of their study). Even with this deviation rate, Uehara et al had no clinically significant complications.

CONCLUSION

Despite being technically demanding, the use of pedicle screws in the subaxial cervical spine is safe, with a low rate of misplacement in postoperative CT scans. Even screws with critical deviation presented few significant clinical complications.

All authors declare no potential conflict of interest related to this article.

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