

MISPLACED PEDICLE SCREWS BY THE FREEHAND TECHNIQUE: WHAT IS THE REAL VALUE FOR THE OCCURRENCE OF NEUROLOGICAL LESIONS?

PARAFUSOS PEDICULARES MAL POSICIONADOS PELA TÉCNICA "FREEHAND": QUAL O REAL VALOR PARA O SURGIMENTO DE LESÕES NEUROLÓGICAS?

TORNILLOS PEDICULARES MAL POSICIONADOS POR TÉCNICA "FREEHAND": ¿CUÁL ES EL VALOR REAL DE LA APARICIÓN DE LAS LESIONES NEUROLÓGICAS?

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ABSTRACT

Objective: To verify the presence of neurological damages in patients submitted to instrumentation with thoracolumbar pedicle screws misplacement. **Methods:** Prospective study with a random selection of 30 patients submitted to pedicular instrumentation by posterior approach with freehand technique. Screws vertebral positioning was comparatively and blindly evaluated with tomographies. Then, we tried to correlate neurological status with screw placement. **Results:** Thirty patients submitted to spinal surgery at this hospital for any disease had instrumentation with 223 pedicle screws. Vertebral pedicle wall violation was observed in 33% of cases, and more than half of them had medial cortical breach. Neurological worsening occurred in three patients in the immediate postoperative period, but only one screw needed repositioning. All patients recovered the previous neurological status. **Conclusion:** A high level of pedicle screw cortical violation was observed. However, small pedicle breaches may originate neurological damages and, when they occur, the lesions are reversible if the misplaced screws are corrected.

Keywords: Spine; Spinal canal; Bone screws; Spinal fusion/instrumentation; Tomography; Radiculopathy.

RESUMO

Objetivo: Verificar a existência de lesões neurológicas nos pacientes submetidos à instrumentação com parafusos pediculares mal posicionados na região toracolombar. **Métodos:** Estudo prospectivo com seleção randômica de 30 pacientes submetidos à instrumentação pedicular por via posterior, pela técnica "freehand". Foi avaliada comparativamente, de forma cega, a adequação do posicionamento dos parafusos nas vértebras por meio de tomografias. A seguir, tentou-se correlacionar a existência de alterações neurológicas relacionadas ao posicionamento dos implantes. **Resultados:** Observados 223 parafusos pediculares na coluna toracolombar em 30 pacientes operados no serviço por diversas doenças. Houve violação da parede do pedículo vertebral em 33% dos pacientes, sendo mais da metade com invasão da cortical medial. A piora neurológica no pós-operatório imediato ocorreu em três pacientes, entretanto apenas um parafuso precisou de reposicionamento. Todos os pacientes recuperaram a situação neurológica pré-cirúrgica. **Conclusões:** O índice de violação cortical com parafusos pediculares mostrou-se elevado. Contudo, nota-se que pequenas violações pediculares podem causar danos neurológicos e que, quando esses acontecem, são reversíveis se o erro for corrigido.

Descritores: Coluna vertebral; Canal vertebral; Parafusos ósseos; Fusão vertebral/instrumentação; Tomografia; Radiculopatia.

RESUMEN

Objetivo: Comprobar si hay lesiones neurológicas en pacientes sometidos a la instrumentación con tornillos pediculares mal posicionados en la región toracolombar. **Métodos:** Se realizó un estudio prospectivo con selección aleatoria de 30 pacientes sometidos a la instrumentación pedicular posterior a través de la técnica "freehand". Se evaluó comparativamente en forma ciega, la conveniencia de la colocación de tornillos en las vértebras con visualización por TC. A continuación, tratamos de correlacionar la presencia de trastornos neurológicos relacionados con la colocación de los implantes. **Resultados:** Fueron observados 223 tornillos pediculares en la columna toracolombar en 30 pacientes operados en el servicio debido a diversas enfermedades. Hubo una violación de la pared del pedículo en un 33% de los casos, siendo que más de la mitad con invasión de la cortical medial. El empeoramiento neurológico en el postoperatorio inmediato se produjo en tres pacientes, aunque fue necesario cambiar la posición de un solo tornillo. Todos los pacientes recuperaron su estado neurológico preoperatorio. **Conclusiones:** La tasa de violación cortical con tornillos pediculares fue alta. No obstante, se observó que las pequeñas violaciones pediculares pueden causar daño neurológico y que cuando esto sucede, es reversible si se corrige el error.

Descriptores: Columna vertebral; Conducto vertebral; Fusión vertebral/instrumentación; Tomografía; Radiculopatía.

INTRODUCTION

The use of pedicle screw fixation in arthrodesis of the thoracic and lumbar spine has been widely established in the surgical community. It is used in the treatment of various diseases and offers great stability to the spinal fusion performed using the posterior approach, since it covers all of the three columns defined by Denis.¹ However, this

technique requires great precision during the approach and positioning of the pedicle screw, as the vertebral pedicle is surrounded by noble anatomical structures. A lack of accuracy during the procedure can lead to complications such as pedicle fractures, or neurological, vascular, or visceral injuries.

The aim of this study was to evaluate the incidence of

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misplaced pedicle screws and assess the correlation between neurological damage and the margin of error in the placement of these screws.

METHODS

One hundred and fifty patients underwent surgical treatment of the thoracic and lumbar spine in one public health hospital in Recife, PE, between February 2010 and February 2011. From this population, thirty patients who were equally divided between both genders were randomly and prospectively selected, underwent arthrodesis by posterior approach for various pathologies. All patients were operated by the same team, consisting of five orthopedic surgeons, four spine surgeons, and a resident doctor in spine surgery.

The study involved fifteen males and fifteen females, whose average age was 39.9 years (11-80 years). There was no restriction regarding the disease addressed through surgery.

The implantation technique used was that reported by Kim et al.² and Li et al.,³ in which the screws were placed freehand. Anatomic landmarks were exposed, including facet joints and transverse processes. The point of entry of the pedicle screw was chosen according to the level approached. In the proximal thoracic spine (T1 to T3), the insertion was performed medially to the junction between the origin of the transverse process and the lamina, and laterally to the *pars interarticularis*. In the middle thoracic spine (T4 to T9), the entry point is located medially at the junction of the proximal portion of the transverse process with the lamina and upper facet, and laterally to the *pars interarticularis*. In the lower thoracic spine (T10 to T12), the screw begins its path at the bisection of the transverse process into its junction with the lamina, and the *pars* laterally. In the lumbar spine, the entry point of the screw is at the intersection of the line that passes through the horizontal middle portion of the transverse process and the vertical line of the junction between the middle and lateral thirds of the superior articular process.⁴

The implants varied in size according to preoperative examinations of the patients, and monoaxial and polyaxial titanium pedicle screws with a diameter of 4.5 to 6.5 mm and lengths according to intraoperative measurements were used. During surgery, the screws were observed using a GE Everview 7500 (www.ge.com/br) image intensifier device in two orthogonal views.

Routine CT scans were obtained on a GE LightSpeed Plus (www.ge.com/br) in a supine position, with 2-mm slices parallel to the pedicles in the sagittal, axial, and coronal planes. We sought to analyze the placement of the pedicle screws regarding the presence of pedicular cortical injury due to the screw. If found, the invasion of the cortical implant was quantified in millimeters. Three parameters were considered in the measurement of breaches of the pedicle in any cortical bone: none, up to 2 mm, and greater than 2 mm, according to Xu et al.⁵ and Polly et al.⁶

A second observer performed a neurological examination in the patients selected in the first ten days after surgery, considering neurological injuries different from those at the admission of the patient to be new. Subsequently, these data were plotted to identify a possible correlation between the screw misplacement and neurological injury.

Statistical evaluation was performed using the SPSS 13.0 software for Windows and Microsoft Excel 2003. We used the chi-square and Fisher's exact test to verify the existence of association between the variables. All tests were applied with 95% confidence.

This study was approved by the Ethics and Human Research Committee of our Service.

RESULTS

The arthrodeses were performed by posterior approach in eight patients with adolescent idiopathic scoliosis, three patients with spondylodiscitis, 10 patients with thoracolumbar fractures, two patients with disc herniation, two patients with spondylolisthesis, three patients with spinal canal stenosis, and two patients with spinal neoplasia. (Figure 1) A total of 223 pedicle screws were placed from T1 to S1. (Table 1)

Tomography evaluation found that 75 (33.6%) screws were violating some pedicle cortex. (Table 2) These breaches occurred in the medial cortex of the pedicle in 58.7% of the implants and laterally in 28% of cases. (Figure 2)

The pedicular lesions were considered acceptable when they were up to 2 mm extravasation of the screw inside the pedicle, and unacceptable if greater than 2 mm. Based on this information, 47 screws (61.8%) presented acceptable placement and 28 (38.2%) unacceptable placement.

We also evaluated the presence of neurological changes in the immediate postoperative period in these patients. Three patients (10%), who had 19 misplaced screws, representing 8.5% of the implant sample, showed root lesions in the first two days post-surgery; there was regression to the neurological pattern pre-arthrodesis on the

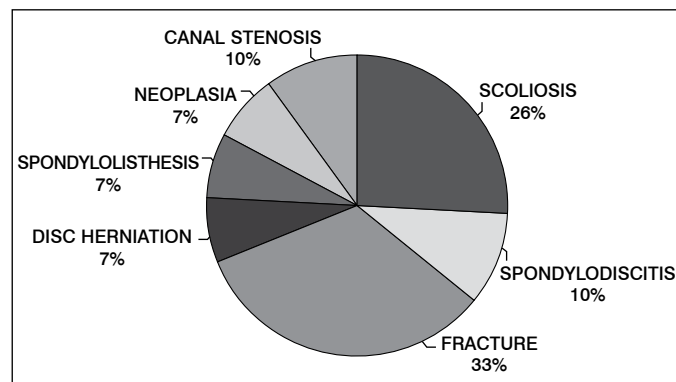


Figure 1. Prevalence of spine pathologies in the evaluated sample.

Table 1. Distribution pedicle screws according to pathology.

Pathology	Screws (n)	%
Scoliosis	89	39.8
Spondylodiscitis	12	5.4
Fracture	70	31.4
Disc herniation	8	3.6
Spondylolisthesis	10	4.5
Neoplasia	16	7.2
Canal stenosis	18	8.1
Total	223	100

Table 2. Distribution by vertebra of the screws that violated the pedicular cortex.

Vertebra	Total number of screws	Misplaced screws (n)	Misplaced screws by level (%)	Misplaced screws (% of total)
T1	0	0	0.0	0.0
T2	2	1	50.0	1.3
T3	2	1	50.0	1.3
T4	7	4	57.1	5.3
T5	5	2	40.0	2.7
T6	7	2	28.6	2.7
T7	7	3	42.9	4.0
T8	5	0	0.0	5.3
T9	10	4	40.0	10.7
T10	14	8	57.1	6.7
T11	20	5	25.0	6.7
T12	24	5	20.8	13.3
L1	23	10	43.5	18.6
L2	23	14	60.9	6.7
L3	24	5	20.8	6.7
L4	20	5	25.0	6.7
L5	18	5	27.8	1.3
S1	12	1	8.3	1.3
Total	223	75	—	100

following days in two patients, who had no invasion into the spinal canal greater than 2 mm, and the findings of which were considered to be radiculopathies after surgical manipulation. They consisted of a patient with a type C fracture of a thoracic vertebra according to Magerl et al.,⁷ and another patient with significant stenosis of the lumbar spinal canal. The patient who showed no improvement was in treatment for spondylodiscitis and presented 4 mm medial invasion of the left T10 pedicle screw, which had to be repositioned at a new surgical time, and the patient evolved with decreased pain and numbness that the patient had previously presented.

Statistical analysis showed there to be an association between the cortical rupture, the emergence of neurologic injury ($p = 0.037$), and the degree of cortical extravasation ($p = 0.045$). There was no significance as to the location of the pedicle cortical breach and the presence of radiculopathy. (Table 3) There was a statistical correlation between neurological changes and surgical pathology ($p < 0.001$).

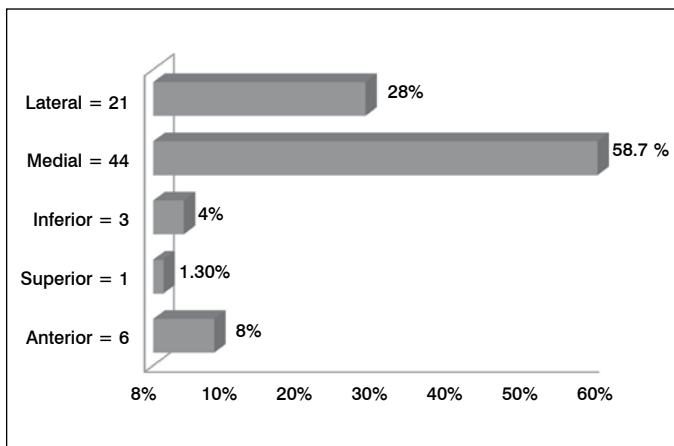


Figure 2. Absolute and relative amount of vertebral pedicle injuries according to the anatomical location.

Table 3. Evaluation of the neurological lesion according to the cortical pedicle rupture, its location, its gradation and pathology.

Variable	Neurological sequelae				P
	Yes		No		
	n*	%	n*	%	
Breach of the vertebral pedicle					
Present	11	57.9	64	31.4	0.037 **
Absent	8	42.1	140	68.6	
Anatomical location of the breach (when present)					
Anterior	0	0.0	6	9.4	0.620 ***
Superior	0	0.0	1	1.6	
Inferior	0	0.0	3	4.7	
Medial	6	54.5	38	59.3	
Lateral	5	45.5	16	25.0	
Degree of breach					
Acceptable	10	90.9	37	57.8	0.045 ***
Unacceptable	1	9.1	27	42.2	
Pathological basis for surgery					
Scoliosis	0	0.0	89	43.7	< 0.001 ***
Spondylodiscitis	4	21.1	8	3.9	
Fracture	8	42.1	62	30.4	
Disc herniation	0	0.0	8	3.9	
Spondylolisthesis	0	0.0	10	4.9	
Neoplasia	0	0.0	16	7.8	
Canal stenosis	7	36.8	11	5.4	

(*) Absolute number of pedicle screws. (**) Chi-square test. (***) Fisher's exact test.

DISCUSSION

Knowing the potential morbid power of the anterior surgical approach for thoracolumbar fusions,⁸ which became one of the factors that influenced the spread of the thoraco-lumbo-sacral spinal fusion technique using a strictly posterior approach through the use of pedicle screws. The free hand insertion technique is widespread among surgeons and direct palpation of the pedicle during screw positioning allows for the perception of cortical extravasation in its path, especially in ruptures larger than 2 mm.⁹ However, a technique requires its learning curve, so this study was hampered when a trainee participated in the positioning of the implants, even when in conjunction with experienced surgeons. Maturity during surgery makes it more likely that these pedicle lesions are noticed prior to implant placement and that it can be repositioned at that same moment.

The misplacement of the pedicle implants is directly and indirectly associated with serious complications, such as infection, pneumothorax, chylothorax, pleural effusion, dura-mater injury, pedicle fracture, implant loosening, and paraparesis.²

In the current literature, extravasation of the medial cortex of up to 2 mm is considered safe in most cases.¹⁰ According to Gertzbein and Robbins,¹¹ there is a zone of up to 4 mm that is considered safe in the medial pedicle, corresponding to 2 mm of the epidural space and 2 mm of the subarachnoid space. The lateral cortex may suffer a breach of up to 6 mm without causing clinical consequences if the in-out-in technique is used.¹² There is also an inherent elasticity to the pedicle of pediatric patients, which can support screws up to 115% without causing cortical injury.¹³

In a diverse sample, poor positioning was observed in 33.6% of pedicular implants, lower than the rate of 79% observed in the laboratory by Bergeson et al.⁹, but consistent with the value of 23% observed by Ravi et al.¹⁰ in lumbar vertebrae, and 43% by Belmont in thoracic vertebrae.¹²

The location of the breach obtained discrepant values in the literature, which was medial in 14 to 30% of cases and lateral in 60 to 68%.^{10,12} In this study, most ruptures were located medial to the pedicle (58.7%), and lateral in 28% of the screws. There is a significant variation in the results. But the studies cited above relate thoracic and lumbar vertebrae in isolation, which was not addressed by these authors.

According to the values shown, the incidence of neurological injuries postoperatively was 10% in the group studied. Ranade et al.¹⁴ found no neurological complications in their study sample, which, however, contained a set of 16 subjects, which affects their final evaluation.

This analysis showed a statistical correlation between the breach and the presence of postoperative neurological changes, but there was no significance between the anatomically incorrect position of the implant and neurological symptoms. It might be said that the vertebrae at a higher risk for pedicle screw misplacement were L1, T12, and T10, in descending order. There was no increase in this index from vertebrae T5 to T8, according to other studies.^{9,12} However, this assessment does not apply when comparing the breaches between similar vertebrae, which may be explained by several vertebrae having received few screws during these procedures and their positioning error having been overestimated.

Thirty-seven point three percent of the cortical breaches, corresponding to 28 of the 75 misplaced screws, extravasated beyond 2 mm of the pedicle, going outside of the safety margin.^{5,6} The acceptability rate for a pedicle breach had statistical significance regarding their propensity to cause neurological damage, but this influence was in favor of lesions considered acceptable or safe, that is, less than or equal to 2 mm. The reverse of this result was expected. The Fisher's exact test showed $p = 0.045$; this value can be justified for a small sample, since only one screw that is misplaced beyond the current 9% would change the test value to be non-significant.

A high statistical association was also shown between spondylodiscitis, fracture, and spinal canal stenosis as diseases prone

to cause neurological damage post-surgically. This trend was due to the sample number of injured patients, which was restricted to three. In a study with a larger sample of patients and screws, this pattern will tend to create a statistical value more consistent with reality. The same occurs between the presence of neurological injury and the vertebra where the screw is located, a calculation that needs greater range of research subjects.

CONCLUSION

There was high incidence of pedicle screws that breached their path, especially towards medial injuries. The margin of more than 2 mm for breaches of the pedicle, although described in the literature as unacceptable, is not consistent with the results of this study, in which an increased incidence of neurological injuries was observed

in screws with a cortical breach of less than 2 mm. However, when present, such lesions may be reversible with the better positioning of the pedicle implant. This test requires evaluation in a broader sample to confirm the hypotheses raised at this time.

ACKNOWLEDGEMENTS

We would like to thank the Orthopedics and Traumatology Department staff and patients of our Service, who assisted in the construction of the database.

All authors declare no potential conflict of interest concerning this article.

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