

# MISPLACEMENT OF LUMBAR PEDICULAR SCREWS THAT PRODUCE POSTOPERATIVE MECHANICAL RADICULALGIA WITH NORMAL INTRAOPERATIVE NEUROPHYSIOLOGICAL STIMULATION: THE VALUE OF NEUROPHYSIOLOGICAL STIMULATION AT THE PEDICULAR MID-TRACK

*MAL POSICIONAMENTO DE PARAFUSOS PEDICULARES LOMBARES QUE PRODUZEM RADICULALGIA MECÂNICA PÓS-OPERATÓRIA COM ESTIMULAÇÃO NEUROFISIOLÓGICA INTRAOPERATÓRIA NORMAL: O VALOR DA ESTIMULAÇÃO NEUROFISIOLÓGICA NO TRAJETO DO PARAFUSO*

*MAL POSICIÓN DE TORNILLOS PEDICULARES LUMBARES QUE PRODUCEN RADICULALGIA MECÁNICA POSTOPERATORIA CON ESTIMULACIÓN NEUROFISIOLÓGICA INTRAOPERATORIA NORMAL: EL VALOR DE LA ESTIMULACIÓN NEUROFISIOLÓGICA DEL TRAYECTO DEL TORNILLO*

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## ABSTRACT

**Objective:** To carry out a neurophysical evaluation that can identify these cases during surgery, and that prevents misplacement of pedicular screws. **Methods:** A total of 6739 screws were placed in 293 patients submitted to scoliosis correction via the posterior route with pedicular screws using the freehand technique. Of this total, eight patients (2.7%), with a mean age of 24 years, developed postoperative radiculopathy. Lumbar CT scans showed 10 misplaced lumbar screws (2L1-3L2-4L3-1L4), with minimal protrusion of the lower part of the screw. EMG thresholds of the screw and track were evaluated. **Results:** In the initial surgery, no anomalies were detected on palpation of the screw track or in the radioscopic control; neither were any neurophysiological alterations detected in the neurophysiological stimulation with t-EMG. All the patients had radicular pain in the standing and seated positions, which disappeared when lying on the bed. The screws were surgically removed at an average of 37 days after surgery (range: 4-182). In this surgical procedure, the neurophysiological monitoring was repeated, again showing normal thresholds (>11mA). After screw removal, stimulation of the probe within the track showed very low thresholds (range: 3.9-10.7 mA) at mid pedicular track. After a mean follow-up time of 4.4 years (Range: 2.6-6.8), five patients reported occasional radicular discomfort, and had minimal motor deficit in the affected limb. **Conclusions:** A type of misplacement of lumbar pedicle screws is presented that produces radicular pain in the standing and seated positions, and that may not be detected by conventional monitoring. Neurophysiological stimulation of the mid pedicular track, after removal of the screw, produces low stimulation thresholds. Systematic stimulation of the track prior to insertion of the lumbar pedicular screw is recommended.

**Keywords:** Radiculopathy; Spine; Bone screws.

## RESUMO

**Objetivo:** Avaliar a exploração neurofisiológica que identifica esses casos no intraoperatório e que evite o mal posicionamento de parafusos pediculares. **Métodos:** Em 293 pacientes submetidos à intervenção para escoliose por via posterior com parafusos pediculares e técnica "free hand", foram implantados 6.739 parafusos. Do total, oito pacientes (2,7%) com média de idade de 24 anos, tiveram dor radicular lombar no pós-operatório. Na TC depois da cirurgia, foram encontrados 10 parafusos lombares (2L1-3L2-4L3-1L4) com proeminência mínima na parte inferior do pedículo. Foram avaliados os limiares EMG do parafuso e do trajeto. **Resultados:** Na cirurgia inicial, não foram detectadas anomalias à palpação do trajeto nem no controle radioscópico; também não se verificaram alterações neurofisiológicas na estimulação neurofisiológica com t-EMG. Todos os pacientes tiveram dor radicular em posição ortostática e sentada, que passava com o repouso na cama. Os parafusos foram retirados cirurgicamente aos 37 dias, em média (R:4-182). Nesta cirurgia repetiu-se a monitoração neurofisiológica, que voltou a mostrar valores normais (> 11mA). Depois da retirada dos parafusos, realizou-se estimulação do trajeto que mostrou, na parte média, limiares inferiores aos valores normais (3,9-10,7mA). Depois de acompanhamento médio de 4,4 anos (R:2,6-6.8), cinco pacientes relatavam incômodos radiculares ocasionais e um tinha déficit motor mínimo no membro afetado. **Conclusões:** Apresenta-se um tipo de mal posicionamento de parafuso pedicular lombar que produz radiculalgia em posição ortostática e sentada, que não é detectado pela monitoração convencional. A estimulação neurofisiológica do trajeto na zona média, depois da retirada do parafuso, produziu limiares baixos de estimulação. Recomenda-se a estimulação sistemática do trajeto antes da inserção do parafuso pedicular lombar.

**Descritores:** Radiculopatia; Coluna vertebral; Parafusos ósseos.

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## RESUMEN

**Objetivo:** Valorar una exploración neurofisiológica que identifique estos casos intraoperatoriamente y evite la mal posición de tornillos pediculares. **Métodos:** En 293 pacientes intervenidos de escoliosis por vía posterior con tornillos pediculares y técnica "free hand", se implantaron 6.739 tornillos. De estos, ocho pacientes (2,7%), con edad promedio de 24 años, presentaron dolor radicular lumbar postoperatorio. En la TC postoperatoria se encontraron 10 tornillos lumbares (2L1-3L2-4L3-1L4) con prominencia mínima en la parte inferior del pedículo. Se evaluaron los umbrales de EMG del tornillo y del trayecto. **Resultados:** En cirugía inicial no se detectaron anomalías en la palpación del trayecto, ni en el control radioscópico, ni alteraciones neurofisiológicas en la estimulación neurofisiológica con t-EMG. Todos presentaron dolor radicular en bipedestación y sedestación que remitía con reposo en cama. Los tornillos fueron retirados quirúrgicamente a los 37 días en promedio (R:4-182). En esta cirugía se repitió la monitorización neurofisiológica y volvió a mostrar valores normales ( $> 11$ mA). Tras la retirada de los tornillos, se realizó estimulación del trayecto que mostró en la parte media, umbrales por debajo de los valores normales (3,9-10,7mA). Tras un seguimiento promedio de 4,4 años (R:2,6-6,8), cinco pacientes referían tener molestias radiculares ocasionales y uno tenía déficit motor mínimo en la extremidad afectada. **Conclusiones:** Se presenta un tipo de mal posicionamiento de tornillo pedicular lumbar que produce radiculalgia en bipedestación-sedestación y que no es detectado con monitorización convencional. La estimulación neurofisiológica del trayecto en la zona media, tras retirada del tornillo pedicular, produjo umbrales bajos de estimulación. Se recomienda estimulación sistemática del trayecto antes de la inserción del tornillo pedicular lumbar.

**Descriptores:** Radiculopatía; Columna vertebral; Tornillos óseos.

## INTRODUCTION

Surgical treatment is an accepted method for correcting and preventing the progression of deformity of the thoracolumbar spine. However, the possibility of radiculomedullary neurological complication during surgery is a major cause of concern for surgeons.

Neurological complications can occur at the moment of insertion of the screws or sublaminar wires/hooks, in the process of neural release or bending of the spine, or at the moment of reduction of the deformity.

The occurrence of pedicle screw misplacement in surgery for deformity of the thoracolumbar spine ranges from 6% to 30%,<sup>1</sup> usually without any neurological consequences.

In larger case series, an incidence of radicular complications during surgical treatment of spinal deformity of between 0.41% and 2.24% has been reported, despite the existence of correct neurophysiological monitoring and other controls.<sup>2</sup>

The rate of radicular complications caused by misplacement of pedicle screws that escaped detection by conventional neurophysiological and imaging systems is reported to be 3.38%.<sup>3</sup>

A mean intracanal deviation of 2 mm is considered acceptable in placement of the pedicle screw, at least in the thoracic region.<sup>1,4</sup>

Multiple intraoperative controls are recommended, such as the technique of pedicle insertion and intraoperative freehand palpation, neurophysiological control with somatosensory evoked potentials (SSEP) and motor evoked potentials (PEM) and monitoring of screws (t-EMG), and finally, intraoperative radioscopic control<sup>5</sup> in patients undergoing surgery for deformity of the thoracolumbar spine.

In relation to the pedicle screw stimulus-evoked thresholds (t-EMG) introduced by Calancie et al.<sup>6</sup> in 1991, there is some discrepancy between authors when it comes to determining the pathological values that suggest perforation of the medial cortex of the lumbar pedicle and close contact with the nerve root. Glassmann et al.<sup>7</sup> suggest lower thresholds of 10 mA as highly suggestive of cortical perforation. Toleikis et al.<sup>8</sup> suggest a threshold of  $< 5$  mA, and Raynor et al.<sup>5</sup> present a stimulus-evoked threshold of 8 mA as unacceptable, due to the possibility of medial perforation of the lumbar pedicle.

According to the scientific evidence and our surgical experience, there are a number of patients with postoperative radicular complications that go undetected despite multiple controls.

The objective of this work is to analyze a group of patients with postoperative pain and/or motor deficit of the lower limbs following surgical correction of spinal deformity, whose symptoms occur exclusively when in the standing and/or seated positions, seeking to improve the neurophysiological detection of misplaced lumbar screws that go undetected in the usual intraoperative controls (freehand pedicle insertion technique, t-EMG and intraoperative imaging control).

## METHODS

We studied 294 patients who underwent surgery for spinal deformity of multiple etiologies between 2004 and 2010, in three hospitals. All the surgical operations were performed by a primary surgeon with wide experience in surgical correction of deformities, assisted by several orthopedic surgeons with experience in spinal surgery, who were actively involved in the insertion of the pedicle screws, particularly on the right side of the patient.

A surgical technique by the posterior approach was used, essentially only with screws.

A total of 6,765 pedicle screws were inserted in these patients: 1,550 lumbar, 5,088 thoracic, and 127 iliac screws.

The screws were inserted freehand in most cases. All patients underwent intraoperative neurophysiological monitoring with potentials (SSEP and MEP) and monitoring of the screws (t-EMG). All patients underwent an intraoperative imaging exam at the end of the surgery, to confirm the correct positioning of the screws.

The neurophysiological study was carried out with a specific intraoperative monitoring Keypoint machine (Alpine Skovlunde-Denmark). The pedicles were stimulated with a pedicle screw Probe (Viasys Healthcare, Madison WI), used as a cathode that sits on the screw head, and a monopolar needle of 12 mm in length (Neuroline Subdermal, Ambu), which was inserted into the paraspinal musculature, acting as an anode.

A constant stimulus current was applied with a frequency of 1 Hz and duration of 0.1 ms, with intensity increasing from 0.2 mA to 50 mA until a repeatable compound action potential was obtained in the muscle of the corresponding myotome. The responses were recorded using filters at between 20Hz and 5 KHz, with amplifier sensitivity 50  $\mu$ V per division and 10 ms of stimulation pulse. A pair of stainless steel monopolar needle recording electrodes, 12 mm in length (Neuroline Subdermal, Ambu), were inserted into the muscles of the corresponding myotomes.

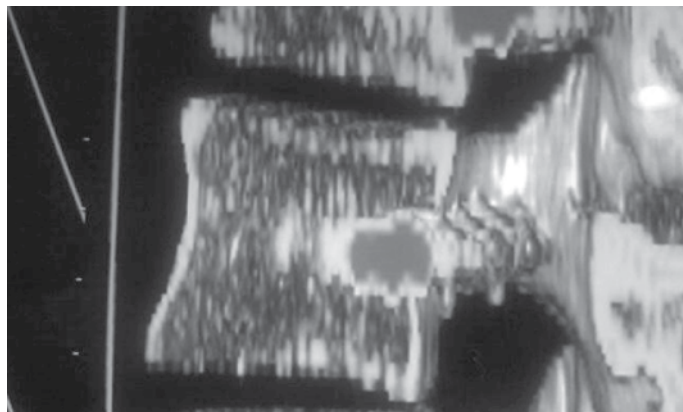
The acceptable thresholds, according to the recommendations of Glassman et al.,<sup>7</sup> were threshold  $> 15$  mA: 98% confidence for the intrapedicular position of the screw. Threshold 10-15 mA: 87% confidence for the intrapedicular position of the screw. Threshold  $< 10$  mA: perforation of the cortex in 90% of cases. In the screws with thresholds below 15 mA, the track was reviewed in all cases and the screw was definitively inserted, according to the palpation assessment, particularly if the threshold was between 10-15 mA and it was considered a fundamental screw.

Statistical analysis was performed using the software program SPSS v 1800 (IBM Corp, Armonk, NY) and the chi-square test of independence for the study of the association between "surgeon's experience" and "outcome of the implant".

Of the 294 patients who underwent surgery, 8 (2.7%) patients with a mean age of 24 years (11-39) developed postoperative radicular pain/motor deficit. An axial computed tomography (CT) was requested in these patients, which showed that 10 (0.67%) malpositioned lumbar screws (2L1-3L2-4L3-1L4), all of them with minimal prominence in the

lower region of the pedicle. (Figure 1) The malpositioned screws were removed, and the EMG thresholds of the screw and pedicle track were assessed during the surgery.

Patients with malpositioned screws presented the following diagnoses: 1 congenital heart disease, 1 infantile cerebral palsy, 1 Marfan syndrome, 3 adolescent idiopathic scoliosis, 1 adult scoliosis, and 1 Scheuermann's disease. (Table 1)



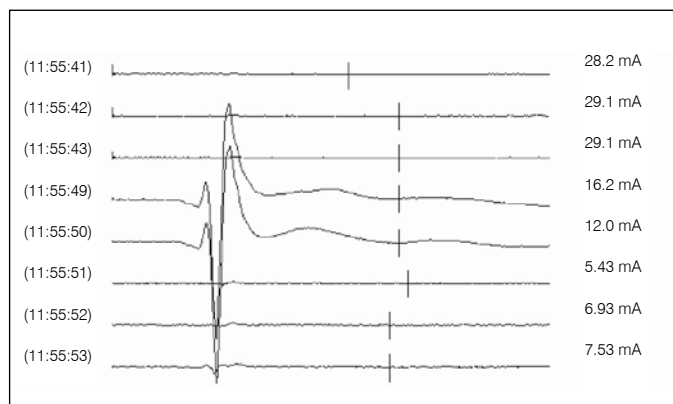
**Figure 1.** Detail of malpositioned screw.

## RESULTS

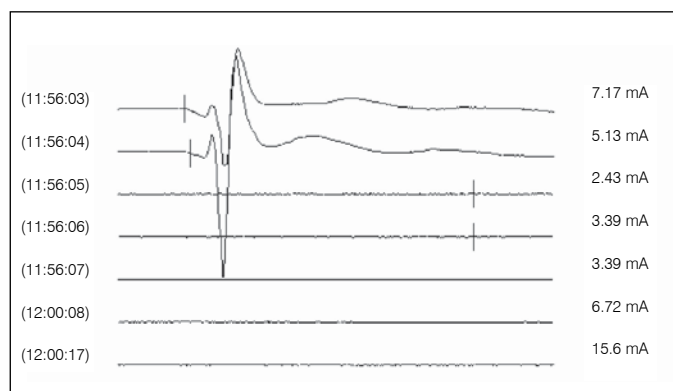
The eight patients with postoperative radiculopathy presented palpation of the track, t-EMG and intraoperative radiography without pathological changes during the first surgery. Postoperative CT showed, in all cases (10 screws) misplacement of the lumbar screw, with invasion <2 mm in the lower region of the pedicle. The screws were removed without replacement at 37 days, on average (4-182).

Prior to removal of the screw, a new stimulation was performed on the malpositioned screw, which once again showed normal values (>11 mA). After withdrawal of the screw, stimulation of the pedicle track was performed, showing very low values in its mid portion (3.9 -10.7 mA) and normal values (> 11 mA) at the bottom of the pedicular track (Figures 2 and 3).

After a mean follow-up of 4.4 years (2-6.8 years), two patients



**Figure 2.** Neurophysiology. Lumbosacral screw stimulation.



**Figure 3.** Neurophysiology. Screw track stimulation.

reported moderate pain in the affected root, one reported mild motor deficit of the quadriceps (L3D), one patient had paresthesia, and four patients were asymptomatic.

The malpositioned screws mainly occurred on the right side of the patient (9/1), a fact that presents a statistically significant relationship, with  $p < 0.05$  (chi-square).

**Table 1.** Data on patients with malpositioned screws.

Patient	Age	Diagnosis	Fixation	COBB	Malpositioned screw	Time to removal of screw	Follow-up symptoms
1A	15	Congen. Heart Disease (Fontan)	T4-L3	48	L2D CONVEX	18 Days	Paresthesias
1B	15	Idem	T4-L3	48	L3D CONVEX	18 Days	Paresthesias
2	39	Cerebral palsy	T3-L4	76	L3D CONVEX	10 Days	Radicular Pain
3A	15	AIS	T2-L3	48	L1D CONVEX	182 Days	Asymptomatic
3B	15	Idem	T2-L3	48	L3D CONVEX	182 Days	Asymptomatic
4	11	AIS	T2-L3	77	L2D CONVEX	24 Days	Asymptomatic
5	36	Marfan	T2-ILIAC	68	L4I CONCAV	23 Days	Radicular Pain
6	38	Idiopathic scoliosis	T2-ILIAC	104	L3D CONVEX	4 Days	Mild paresis quadriceps
7	14	AIS	T2-L3	67	L1D CONCAV	31 Days	Asymptomatic
8	18	Scheuermann's	T2-L4	100	L2D	6 Days	Asymptomatic

## DISCUSSION

All the patients presented pain in the standing/seated position in the metamere of the affected root, which disappeared when lying down. All the cases had low levels of track stimulation (t-EMG) in the mid-pedicle region after removal of the screw, which suggests greater sensitivity to detect an abnormal positioning of the lumbar pedicle screw, compared with direct stimulation of the screw.

We believe that the presence of symptoms mainly in the standing/seated positions is related to the decreased height of the disc that occurs in both positions, while the presence of rigid instrumentation in the vertebra adjacent to the disc is a drawback for attributing the pathogenesis of the symptoms to the decreased disc height. However the discs retain some mobility in spite of the posterior instrumentation.

Most malpositioned screws are on the right side of the patient, which coincides with the position in which the less experienced surgeon stands. Statistical analysis shows a causal relationship between the surgeon's experience and the likelihood of misplace-

ment of the pedicle screw for a level of significance  $\alpha$  of 5%, but not for a significance  $\alpha$  level of 1%.

## CONCLUSIONS

Neurophysiological stimulation of the mid track of the pedicle screw in the lumbar region showed low thresholds (<11 mA) in all cases.

In patients who underwent surgery for vertebral deformity, track stimulation can detect misplacement of lumbar screws that go unnoticed in the normal controls.

We recommend systematic stimulation of the lumbar pedicular track in patients undergoing surgery for vertebral deformity.

There is a statistically significant relationship between the surgeon's experience and lumbar pedicle screw misplacement.

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

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