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Intraoperative Neurophysiological Changes Induced by Thoracic Pedicle Screws Intentionally Placed Within the Spinal Canal: An Experimental Study in Pigs

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Abstract

Study Design: Experimental study,
Objectives: To document and analyze the neurophysiological changes during spinal cord monitoring when thoracic pedicle screws are intentionally placed within the spinal canal.
Summary of Background Data: Although the rate of misplaced screws is relatively high, few patients have neurological impairment. This suggests that a significant degree of medullary displacement and/or compression is necessary to produce neurophysiological changes.
Methods: The spinal cord of 3 experimental pigs was surgically exposed at 3 different levels (T11, T9, and T6). Two pedicle screws were placed within the spinal canal at each vertebral level under direct vision. One was placed on the lateral edge of the dural sac, causing only a slight cord displacement; a second screw was placed in the middle of the spinal canal, producing marked displacement of the neural structures. During the procedure, neurophysiological monitoring of the spinal cord was performed.
Results: No neurophysiological changes were observed in any screws placed at the lateral edge of the dural sac for 20 minutes after screw placement. When the screws were placed in the center of the spinal canal, neurophysiological changes occurred with a mean latency of 10.1 $\pm$ 2.1 minutes, and at 11.6 $\pm$ 1.9 minutes there was complete loss of the spinal cord evoked potentials in all cases. After these centered screws were removed, evoked potentials began to recover, with a latency of 9.7 $\pm$ 3.0 minutes in 7 of 9 cases.
Conclusions: Neurophysiological monitoring of the spinal cord does not detect moderate compression even 20 minutes after neural compression. Only thoracic pedicle screws provoking marked displacement of the spinal cord were able to cause delayed neurophysiological changes leading to loss of spinal cord evoked potentials, which in 22% of cases did not recover after the pedicle screw was removed.

Keywords: Pedicle screws; Complications; Neurophysiologic monitoring techniques

Introduction

Malpositioning of a pedicle screw that invades the spinal canal may cause direct spinal cord damage. The fibers of the lateral corticospinal tract are especially vulnerable if a medial violation of the pedicle cortex of the vertebra occurs [1]. However, the true incidence of neurological complications after the insertion of pedicle screws is unclear [2], and the extent of screw compression necessary to produce neurophysiological changes is also unknown.

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According to several clinical studies [2-6], current intra-operative neurophysiological monitoring techniques do not always accurately predict the presence of thoracic pedicle screws placed within the spinal canal. In fact, a relatively high proportion of thoracic screws invading the spinal canal are not detected by the current intra-operative neurophysiological techniques. In a recent systematic review, misplacement was the most commonly reported complication of thoracic pedicle screw placement [7]. According to this review, the rate of screw malpositioning in studies with postoperative computed tomography scans was as high as 15.7% of all inserted screws [8-10].

In addition, an incorrect screw position does not necessarily imply neural damage. Although the rate of misplaced screws reported is relatively high, few patients have neurological impairment. This is a consistent finding in the literature [7], and it suggests that a significant degree of medullary displacement and/or compression is necessary to produce neurophysiological changes [1,11,12].

The goal of this experimental study was to analyze neurophysiological changes induced by thoracic pedicle screws intentionally inserted within the spinal canal.

Materials and Methods

The authors obtained ethical approval for this study from the research ethics committee of their institution. Three experimental pigs (Large-White) weighing between 30 and 40 kg were sedated by an intramuscular injection of 10 mg/kg ketamine. A peripheral venous catheter was placed in an auricular vein, and intravenous thiobarbital, atropine, and diclofenac were administered. The animals were intubated and anesthetized with sevoflurane, whereas fentanyl, remifentanil, and vecuronium bromide were used as analgesics. Mechanical ventilation, including the continuous monitoring of oxygen saturation, blood pressure, and heart rate, was performed.

Through a midline posterior longitudinal incision over the spinal processes, the thoracic spine of the pig was exposed from vertebrae T5 to T12, and a right hemilaminectomy was completed at T11, T9, and T6, exposing the dural sac. Thoracic pedicle screws 4.5 mm in diameter (Medtronic Sofamor Danek, Memphis, TN) were intentionally inserted, invading the spinal canal and displacing the spinal cord at the selected hemilaminectomy sites (T11, T9, and T6). The screws were placed under direct vision, taking special care to preserve the dural sac from possible tears.

After each pedicle screw was inserted, neurophysiological spinal cord monitoring was performed using 2 epidural catheters: 1 stimulating proximally to the level of pedicle screw insertion and the other recording distally to the pedicle screw, with Keypoint equipment (Medtronic, Skovlunde, Denmark). A constant stimulation current of 1 Hz for 0.2 ms with an increasing intensity between 1 and 5 mA was applied until a reproducible and stable cord-to-cord potential was obtained. Responses were registered

Fig. 1. Pedicle screw with invasion of the spinal canal causing marked displacement of the dural sac.

using filters between 50 Hz and 5 KHz, an amplifier sensitivity of 50 μV, and a sweep duration of 1 millisecond.

The first pedicle screws were placed on the lateral edge of the dural sac, causing only a slight cord displacement starting at the most distant level (T11) and moving toward the most proximal cord level (T6). After the authors monitored these screws, they placed a more medial pedicle screw in the center of the spinal canal, producing marked displacement of the dural sac and spinal cord (Fig. 1); these medially placed screws were also inserted in a distal to proximal sequence. To make the technique consistent, identification of the entry point within the spinal canal was done using a caliper. Use of the caliper under direct vision permitted a reproducible and accurate technique for screw misplacement. Thus, the researchers identified the entry points at the middle of the spinal canal after measuring the canal width and calculating the middle point in each spine level in which the screws were placed (Fig. 2).

Spinal cord neurophysiological monitoring was performed during and after insertion of the pedicle screws for

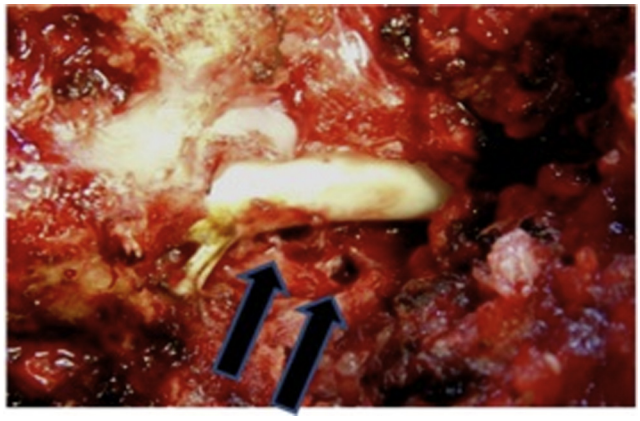

Fig. 2. Point of insertion of the lateral and medial screws.