ORIGINAL ARTICLE

Diathermy Stimulation to Avoid Nerve Injuries during Trans-pedicular Screw Placement in Dorso-lumbar Spine

LIAQAT MAHMOOD AWAN, MUKHTAR AHMED, AZAM NIAZ
Anjum Habib Vohra
Department of Neurosurgery, PGMI / Lahore General Hospital, Lahore

ABSTRACT

Objective: *To demonstrate the utility of diathermy in avoiding nerve injuries due to misplacement of trans-pedicular screws (TPSs) during Dorso-lumbar spinal fusion.*

Study Design*: Retrospective study*

Place and Duration of the Study: *Department of Neurosurgery, Lahore General Hospital, Lahore, from Oct. – 2007 to Oct. 2012.*

Materials and Methods: *In this retrospective study, diathermy was used to assess whether a screw deviated from the pedicle by observing synchronous leg movements caused by intermittently touching a diathermy to the pedicular instrument. Diathermy was performed in 159 cases in which 561 pedicle screws had been placed.*

Results: *Leg movements were observed in 36 cases and the sensitivity of diathermy was 82.7%, the specificity of 98.6%. No neurological complications associated with the placement of pedicular screws were observed after adding diathermy stimulation to the conventional methods.*

Conclusion: *Diathermy may be helpful to avoid nerve injuries during transpedicular screw placement.*

Key Words: *Diathermy, Trans-pedicular screws, Dorso-lumbar spine, Nerve injury.*

Abbreviations Used: *CT = Computed Tomography; DSEP = Dermatomal Sensory Evoked Potential; ESMG = Electrically Elicited Electromyography; EMG = Electromyography; MEMG = Mechanically Elicited EMG; TPS = Trans-pedicular Screw; SSEP = Somatosensory Evoked Potential.*

INTRODUCTION

Although TPS fixation is a prevalent technique in the Dorsolumbar spinal fusion, nerve injury due to screw misplacement is one of the most serious complications. According to the authors of most previous studies, the incidence of neurological complications associated with TPS misplacement can be as high as 17%.[6]

Several assistive modalities like fluoroscopy, intraoperative radiography with radiopaque markers, or palpation of the pedicle wall are used to place TPS accurately. Recently, computer navigation has been reported to be more accurate, but this is expensive, time consuming, may lead to excessive radiation exposure, and is not available in every institution.

Electrophysiological studies have been performed as an adjunct to imaging to confirm that screws are correctly positioned; such studies include the monitoring of SSEPs, DSEPs, and observing the myogenic activity with EMG in response to electrical or mechanical stimulation.

We used simple diathermy as a method to avoid nerve injury by observing the leg movements produced by electrical stimulation through the pedicle instrument from the diathermy. The efficacy of diathermy in preventing neurological complications has not been determined. Our study was designed to determine the effectiveness and limitations of diathermy.

MATERIALS AND METHODS

Placement Technique Trans-pedicular Screw

Prior to laminectomy, TPSs are placed as follows:

1) An initial hole is made using the pedicle seeker at the intersection of the midline of transverse process and the superior facet joint.
2) The surgeon confirms whether perforation has occurred by palpating the inside of initial hole using a sounder.
3) Anteroposterior and lateral screw placements are checked using radiographic visualization of a radiopaque marker.
4) When steps 1, 2, and 3 have been performed without complications, tapping or insertion of the screw is performed.

Diathermy is performed during steps 1, 2, and 4. The surgeon intermittently touches the diathermy to various parts of the pedicle instrument such as the pedicle seeker, sounder, tap, and screw. If there are any leg movements, screw placement is stopped and the surgeon touches the diathermy to the instrument three additional times. When synchronized leg movements are observed in more than three separate instances, diathermy is defined as positive and screw placement is discontinued. When there is no leg movement or the synchronized movements are observed in only one to two instances, the diathermy is defined as negative and the placement is continued. It is not difficult to find leg movements through the surgical drapes. These movements may vary from very strong overall contractions to simple contractions.

Trans-pedicular Screws Misplacement

When diathermy was positive, the instrument was removed and deviation was checked by palpation, using a sounder from inside the pedicle hole, or by inspection of the spinal canal. When screw deviation was found, the direction of the screw was changed or the screw placement procedure was stopped. In cases where diathermy detected no abnormalities, inspection was performed to assess the pedicle wall after laminectomy.

Inspection of the spinal canal was not performed where decompression was unnecessary. In cases in which diathermy changed from positive to negative by altering the direction of the instrument and no perforation was found, the screw was placed in the new direction. Where as in cases in which diathermy remained positive despite the change in the direction, the screw placement was stopped. At levels where decompression was unnecessary, we could not check the instrument deviation except through palpation with a sounder.

Post-operative radiographic studies were evaluated by one of the authors and by the surgeon in charge. Screw placement was judged to be deviated when both the observers thought the screw thread definitely penetrated the cortex of pedicle.[12]

Pre-requisite for Diathermy Stimulation

Muscle relaxant should only be used during intubation. At our institution, atracurium bromide was used as a muscle relaxant and isofourane as inhalational anesthetic. We asked anesthetist not to administer a muscle relaxant until TPS placement procedure was completed. Before the diathermy stimulation, surgeons should confirm that a muscle relaxant has not been administered; this can be done simply by checking the motor response of the paravertebral muscle via appropriate application of the diathermy.

Mode and Strength of Diathermy

An electric diathermy has a cut and coagulation mode. The coagulation mode was used for diathermy stimulition because of its lower power. The output strength was determined by the minimum strength in which the para-vertebral muscle responded when touched by the diathermy. We used electric diathermy made by the Valley LOVE Co. whose output scale is from 0 – 10. Usually thediathermy is applied as a coagulator at scale 6. Diathermy was developed based on the initial observation that leg movements occurred when adiathermy set at an output of scale 6 accidently touched the placement screws later found to be deviated. We adopted scale three as the minimum strength to reduce false – negative results. Thus with any type of diathermy, the stimulation level can be determined based on output level, using an output level 1 scale above the minimal output needed to elicit a response of the paravertebral muscles.

Diathermy Application

Application of the diathermy to the pedicle instrument should be performed intermittently .In diathermy, high frequency current is used to avoid adverse effects on the electrophysiological functions of the heart and muscles. The reason muscles responded to the diathermy stimulation is that direct current is produced only at the moment when the diathermy touches the instrument. This does not occur if the diathermy touches the instrument continuously.

Clinical deterioration due to the placement of the TPSs was judged by the aggravation of leg pain or the new occurrence of paralysis during hospitalization.

RESULTS

In 159 cases, most of which involved trauma and degenerative disease, a total of 561 screws were placed from T_{11} to L_4. All of the screws were made of titanium alloy. Diathermy was positive in 36 cases including four false positive results (11.1%). Diathermy was negative in 525 cases, of which 6 (0.47%) were false negative results. In 08 cases, a potential deviation could not be determined (Table 1).

Table 1: *Summary of findings obtained in 159 cases in which 561 TPSs were placed.*

Factor	No of screws						
	T_{11}	T_{12}	L_1	L_2	L_3	L_4	Total
Instrumentation	61	165	160	85	60	30	561
Diathermy positive	1	9	10	8	5	3	36
False positive	0	2	1	1	0	0	4
False negative	1	3	1	1	1	0	7
Unknown	0	2	1	2	2	0	7

In 36 diathermy positive cases, 16 responses were elicited during the creation of the initial hole with the pedicle seeker. Instrumentation deviation was confirmed in 12 cases ___ in 11 cases by palpation using a sounder and in one case by inspection after laminectomy. Screw misplacement in the remaining 04 cases could not be confirmed, despite checking the medial and posterior pedicle walls during inspection of the spinal canal. A CT study demonstrated that screw placement was correct in these 04 cases and thus these findings were judged to be false positive results.

In 03 cases, no leg movements occurred during the initial screw hole drilling with the pedicle seeker, but the leg movements were then noticed when a sounder was used to inspect the pedicle hole. In these 03 cases, the perforation of the pedicle wall was found by palpation performed concurrently with leg movements.

In 16 cases no leg movements occurred during the initial creation of the pedicle hole or during the inspection with sounder. Perforation was not found by palpation with a sounder, and radiography did not show any abnormalities, but leg movements occurred during tapping or screw insertion. After the tapping or screw insertion, no perforation could be discovered by inspecting the pedicle hole with a sounder. In 09 of these cases screw misplacement was confirmed during the inspection of the spinal canal after laminectomy. In the remaining 07 cases, confirmation of the deviation was not sought because additional laminectomy levels could not be surgically justified. In 03 of the 07 cases, we inserted the screw in a new direction, positioning it more towards the center of the pedicle, based on the intraoperative radiography and then confirmed that the leg movements stopped after this change in direction. In the remaining 04 cases, insertion was stopped because diathermy remained positive after several attempts at changing the screw direction.

If un-confirmed cases are excluded from consideration, the sensitivity of diathermy was 82.7% (24 of 29 cases). Sensitivity was considered to be 75% (27 of 36 cases), assuming that the 03 cases in which leg movements disappeared after changing the direction represented true positive results and the remaining 05 cases in which leg movement did not disappear after change of direction were false positive results.

In 525 TPS placements, no leg movements (01 or 02 leg movements in several cases) were observed. In 04 of these, screw deviation was confirmed during inspection of the spinal canal, and the screw were removed and redirected. In two insertions, screw deviation was confirmed by CT scanning after surgery, and one case represented a reoperation. Consequently the specificity was 98.6% (518 of 525) as these 06 cases represented false negative results.

Post-surgical complications were seen minimal. In one case, a new onset leg pain appeared on 2nd post-operative day after the patient developed a hematoma, which improved after clot was evacuated. Leg symptoms improved in all patients except this case.

DISCUSSION

Trans-pedicular screw fixation is commonly used technique in spinal fusion. Authors of few studies have reported an absence of nerve injuries in TPS while majority of studies revealed nerve injuries due to screw misplacement in the voluminous literature on TPS surgeries. Weinstein et al.[28] reported that the incidence of screw deviation was 285 in a cadaveric study in which they used two way fluoroscopy. It is possible that the incidence would be increased in live surgeries, as these procedures are more difficult secondary to the issues such as bleeding and so on. According to the authors of the clinical reports, the highest incidence of screw deviation was 37%, and that of TPS – related nerve injury was 17%.[6] Computer navigation is considered to improve the efficacy of screw placement, but this technology is not available at every institution because of expense, time consideration, and concerns about excessive exposure to radiations.

Electrophysiological modalities are another option to assess hardware placement. These include monitoring.

Somato Sensory Evoked Potential (SSEP) or

Dermatomal Sensory Evoked Potential (DSEP),

EMG of the muscle response to the mechanical stimulation with pedicle instrumentation (MEMG) [23], EMG monitoring of muscle response to electric stimulation with pedicle instrumentation (EEMG).[5]

Recording of SSEPs is used as a spinal cord monitor but is not suitable for monitoring nerve roots.[13] Monitoring of DSEPs can be used to assess the nerve roots but it is too imprecise for monitoring screw placement and accumulation of the response is necessary to get the desired results.[24]

Use of MEMG in Monitoring

Free running EMG detects mechanical stimulation of the nerve root by transpedicular instrumentation in MEMG. Owen et al.[23] reported that MEMG made it possible to avoid nerve injuries with high probability and demonstrated that this modality can be used during the dynamic phase, which is the moment when nerve injury occurs. In these initial reports the authors stated that false negative and false positive rates of MEMG were 0%. Toleikis et al[30] however, reported the results of a study in which 3409 screws were placed in 662 cases, yielding different results. They observed that MEMG failed to deliver a warning in 51 cases, and the resulting screw misplacement necessitated the replacement of the screw. Another potential problem of the MEMG is that it does not work in the static phase after the completion of the screw placement.

With EEMG, developed by Calancie et al.[5] surgeon send an electrical current to the pedicle screw hardware and monitor the EMG – documented changes of the corresponding muscle. When the screw has perforated the pedicle wall, the EMG – documented change can be detected because the nerve root responds to the increased electrical current from the instrument to the nerve root secondary to the decreased electrical resistance of the pedicle. In the first clinical report by Calancie et al. the authors reported a false negative rate of 0% and false positive rate of 13% when using a stimulation threshold of 7 m A.

Many researchers have since tried various stimulation thresholds ranging from 6 to 15 m A in EEMG to increase the detection rate.[3,12,17,19,30] Lenneke et al.[17] reported that:

1. Threshold greater than 8 m A meant the hardware remained entirely in the pedicle.
2. Threshold less than 4 m A strong likelihood of a defective pedicle and possible contact with the nerve root or dura-mater.
3. A threshold between the 4 and 8 m A meant the potential for pedicle wall perforation.

Lenneke et al. stated that this figure was not absolute and that palpation, radiography, and visualization of the screw must all be taken into account to determine if placement is correct. These vague results concerning the thresholds of EEMG reflect the fact that muscle relaxant levels, the electrical resistance of pedicles, and the patient, with threshold of a compressed nerve root being especially high.[7,14] **Limitation of the EEMG** include the inability to determine the definite threshold at which one can ascertain screw deviation without risk to the patient and inability to pinpoint the moment when nerve injury occurs.

Use of Diathermy as Monitoring

Diathermy is the same as EEMG in theory but different in the detection of the muscle response and the electrical stimulation. In the diathermy, inspection of leg movements replaces the EEMG monitoring to detect the muscle response, and diathermy replaces the electrical stimulator. Although the strength of the stimulating current in diathermy is unknown, in our hands the strength of the current produced by the diathermy was within proper range as both false positive and false negatives occurred. According to the study in which authors examined the minimum current necessary for response in paravertebral muscles, the range of minimum current was 1.8 to 3.6m A in 10 cases (unpublished data). This result shows that the stimulating current used for diathermy is greater than 3.6 m A. This value is a little lower than that reported by other researchers (range 6 – 15 m A).

Although the sensitivity of EMG seems greater than the inspection of leg movements to detect the muscle response, Bosnjak and Dolenc[4] reported that the threshold that leads to the mechanical response in the ankle was significantly lower than that necessary to elicit the corresponding muscle action on the EMG and that monitoring of torque may be a more sensitive indicator of pedicle wall defects that an evoked EMG–documented response. This finding indicates that the **inspection of the leg movements can replace EMG monitoring.**

In diathermy, unexpected phenomena occasionally occur. Although we defined **positive diathermy** as synchronized leg movements occurring more than three times after touching an electric knife to the hardware, leg movements sometimes occurred only once or twice.

Negative Diathermy

We had several cases in which the third touch of diathermy to the screw caused no leg movements despite keeping the instrument at the same position. We defined such cases as **negative diathermy**. A minimum of three consecutive muscle twitches must be observed to consider diathermy positive, but the mechanism is not clear. The fact that there were three cases in which insertion of a sounder caused leg movements despite of absence of leg movements during pedicle probe insertion shows that the mechanism of EEMG cannot be explained simply by the decrease in the electrical resistance due to perforation of pedicle wall. Toleikis et al.[30] also have stated that there are incompletely understood phenomena in EEMG.

One possible disadvantage of diathermy is thermal nerve injury from the electric stimulation. There were no cases in which there were symptoms consistent with heat injury of the nerve root or dura mater, and inspection after laminectomy revealed that there were no burn marks on the nerve root in positive – diathermy cases. Histological evaluation of the skin touched by an electric knife through Pedicular Screw (PS) inserted to the vertebral body revealed no evidence of thermal injury.[26] Consequently; we conclude that the risk of heat injury in diathermy is minimal, although we cannot determine if diathermy causes subclinical nerve damage that may be revealed as yet undeclared symptoms.

There a minimal number of reports regarding the use of EEMG in large patient samples, although there are numerous reports about EEMG in which authors aim to determine the optimum threshold of stimulation. In a report of 3409 screw placements in 662 cases, Toleikis et al.[30] stated that in EEMG in which the threshold was determined as 10 m A, stimulation current was lower than the threshold in 102 cases (15.4%) in 133 screws (3.9%) and 51 screws were removed because of the risk confirmed by the inspection. These findings resulted in a false positive rate of 61.7% (82 of 133) and a false negative result of only 0.03% (01 screw).

Diathermy was associated with a false positive rate of 11.1% and a false negative rate of 1.3%. Although diathermy had a higher false negative rate than EEMG in the study by the Toleikis et al. diathermy was able to identify misplacements that radiographic controls had missed. Additionally, diathermy has several advantages over conventional EEMG. It does not require extensive training and does not require an EMG machine in the operating room. It works not only in the dynamic phase during the insertion procedure but also in the static phase after the completion of screw placement.

In our study, no neurological complications was observed due to screw misplacement occurred by adding diathermy to conventional radiographic control and palpation during 561 screw placements in 159 cases. The incidence of nerve injury by TPS misplacements has previously has been reported as ranging from 0% to 17%, with an average of 1.8%. Analysis of our results shows that diathermy is useful addition to avoid nerve injuries in TPS placement.

CONCLUSIONS

The use of diathermy stimulation in 159 cases in addition to conventional radiography and palpation resulted in no neurological complications due to screw misplacement. The sensitivity and specificity of diathermy in determining TPS deviation were 82.7% and 98.6%, respectively. Diathermy is very simple, easy, quick, works in both the dynamic and static phases. Diathermy can find deviation not detected by conventional methods. Because diathermy is cost effective, the addition of diathermy stimulation is advantageous for prevention of nerve injuries in TPS placement in dorso-lumbar spine.

Address for Correspondence:
Dr. Liaqat Mahmood Awan
Department of Neurosurgery, LGH, Lahore
Ward No. 15, Professor Office
E-mail: drliaqatawan@hotmail.com

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