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Free Hand Posterior Instrumentation of The Thoracic and Lumbar Spine: An Analysis of the Position of 101 Screws in a Major Teaching Hospital in Uganda

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Abstract

Background: Posterior spine stabilization with pedicle screws using the "Free-hand" technique has gained favor among surgeons in resource limited settings due to shortage of radiological facilities to assist in the same procedure. However, this technique comes with potential risks. At this hospital, only the free-hand technique is used for all the patients that need posterior spine stabilization with pedicle screws

Methods: In a series of 19 patients who were operated upon in a period of 8 months with a total of 101 pedicle screws, the position of the screw was analyzed post-operatively using computerized tomography (CT)-scan. The presenting pathology, gender, age and vertebra level instrumented were noted. The relationship between these demographic factors and the accurate positioning of the screw was analyzed.

Results: Most of the screws, 100 out of 101, were within the confines of the pedicle cortices. One screw was positioned 3.29mm beyond the medial cortex at T7 level but was asymptomatic. The age, sex and level of fixed vertebra did not influence the accuracy of screw positioning.

Conclusion: Posterior stabilization of the spine using the free hand technique is generally safe in the spine unit of Mulago national referral hospital, provided the anatomy of the spine is taken into consideration.

Keywords: Free-Hand; Pedicle; Screw Insertion; Violation

Introduction

Orthopedic surgeons have become comfortable with the complex anatomy required for accurate screw placement in posterior spine instrumentation both in the thoracic and lumbar regions [1-3]. Posterior spine instrumentation with pedicle screws and rods offers an overall construct rigidity allowing the stability necessary for spinal arthrodesis and improvement of deformity correction from a number of causes due to its three-column control over the spinal elements. However, pedicle screw placement comes with some complications especially if performed with the "Free hand technique" (placement of the screws without radiological assistance). These complications include; dural tears and Cerebral spinal fluid leakage, nerve root injury and spinal cord injury. To minimize these complications, a thorough knowledge of the anatomy-(osteology)-of the vertebra is a prerequisite. This will allow correct identification of the entry point into the posterior aspect and stay within the pedicle cortex [4-7].

Ideally, the pedicle screw should be centrally positioned without violating any of the cortices of the pedicle. Most dangerous violations are the medial and inferior violations of the cortices. Violation of the medial cortex of the pedicle by the introduced screw can be followed by injury to the dural sac and spinal cord, while violation of the inferior cortex can result into nerve root injury at a given vertebral level [7,8]. Pedicle screw violations as measured using CT-scan has been classified [9] as follows: Grade I Violations: Screws that abut the cortex without extending beyond

the pedicular cortical margin; Grade II Violations: Screws that extend less than 2 mm beyond the pedicular cortex; and Grade III Violations as screws that extend more than 2 mm beyond the pedicular margin. The factors that may influence correct placement of the pedicle screws include but not limited to; a) use of intra-operative imaging to assess entry point, direction, lateral projection and correct vertebral level, b) demographic factors such as age and gender, c) level of vertebral spine fixed-thoracic, lumbar or sacral and d) the surgeon's skill [10]. The methods used to aid accurate insertion of the pedicle screws include: the free hand technique - which exploits the surgeon's knowledge of the spine anatomy, Fluoroscopy guided technique, Computed tomography CT- based navigation and Fluoro- based navigation [11,12]. At Mulago National referral and teaching hospital, posterior spine instrumentation is popularly performed with pedicles screws and rods using the free hand technique. It is hypothesized that the radiological outcome of this technique performed in whatever underlying spine pathology is not completely accurate. So, we performed this study with an aim of describing the positions of pedicle screws placed with the free hand technique in spine surgeries performed at Mulago hospital in different gender and age groups.

Materials and Methods

Following approval from the institutional research and ethics committee, an eight-month (1st August 2013 to 30th March 2014) study was conducted at Mulago hospital spine unit. Mulago is the National referral and major teaching hospital of Uganda. It has a spine unit which is under the department of orthopedics. The spine patients coming to Mulago are mostly referrals from all other lower level health facilities (regional referral hospitals, district hospitals, health center IVs, IIIs and IIs) in Uganda, referrals from South Sudan, Eastern Congo, Western Kenya and Northern Tanzania. These patients go through a screening process, clinical examination and basic laboratory and radiological investigations before admission to the spine unit. The team in the spine unit is headed by a consultant orthopedic surgeon and cares for a range of patients including but not limited to those with traumatic spinal injuries, spinal tumors, spine degenerative diseases, scoliosis and infections. On average, six patients undergo spine surgery per week, two of whom undergo posterior instrumentation with pedicle screws.

Patients

All Patients who underwent posterior spine instrumentation with pedicle screws were included. Informed consent was obtained from included patients to participate in the study. Patients undergoing revision spine instrumentation surgery were excluded. Enrollment was at the time when the consultant spine surgeons took the decision to operate on the patient. Relevant pre-operative patient workup including Computerized tomography-CT and Magnetic Resonance Imaging-MRI of the spine were done. During the study period, there was no portable x-ray unit or any other form of radiological imaging facility available in the spine theater to aid intra-operative screw insertion or immediate post-operative cross-checking of the position of the screw before skin closure. However, within the first seven post-operative days, the position of the pedicle screw was assessed using a plain CT of the operated site. If the screw was not positioned in the center of the pedicle, its medial or inferior position was taken as a medial or inferior violation of the pedicle respectively. A dangerous violation was considered if the screw was completely outside the medial or inferior cortex of the pedicle (In this study a Grade III violation in the medial or inferior cortex was considered dangerous).

Each CT scan was analysed by two consultant radiologists. Where there was disagreement an opinion from a third consultant radiologist was sought to resolve the difference. All data were collected using a pre-tested questionnaire. Noted data included i) independent variables (patient age, sex, diagnosis, vertebral level fixed, number of screws fixed) and ii) dependent - (the position of the screw)

Surgical Technique

A rongeur was used to expose the cancellous entry point of the pedicle. The anatomical landmarks for the entry point were the transverse process, superior articular process and pars interarticularis. The center point of this bony confluence was selected as the entry site. A start hole was made using an awl, and then a pedicle finder used to make the required depth of the hole. The tract was palpated using a ball-tipped probe to confirm the presence of circumferential bone. Holes were tapped with an undersized tap, and then pedicle screws were placed. Based on the fact that the diameter of the pedicles increases from cephalad to caudad, all thoracic spine pedicles were fixed with screws of diameter 4.5mm while all lumbar and sacral pedicles were fixed with screws of diameter 5.0mm. The rods were inserted on screw heads and fixed in position using locking nuts. The surgical wound was lavaged with normal saline, a drainage tube inserted and the wound closed in the standard way. All surgical procedures were performed by two consultant spine surgeons of similar training backgrounds and working experience.

Statistical analysis

For analytical purposes the spine level fixed was classified into upper thoracic, Mid thoracic, Lower thoracic, Upper lumbar and Lower lumbar; to represent thoracic levels 1 to 4, thoracic levels 5 to 8, thoracic levels 10 to 12, lumbar levels 1 to 3 and lumbar level 4 to sacral level 1 respectively. Age was categorized as follows; 20-29years, 30-39years, 40-49years, 50-59years and 60-69years. The position of the screw was summarized according to the Youkilis et al9 system of grading pedicle screw violation of media and inferior pedicle cortices. Patient demographic and data accruing to a particular screw were documented and analyzed independently. Continuous variables are presented as means with standard deviations or medians with ranges, categorical variables

are presented as numbers with proportions. The chi-square test or the Non-Parametric Fisher exact tests were performed when appropriate. The IBM SPSS Statistics version 20 statistical programme (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. A p-value less than 0.05 was considered statistically significant.

Results

Over a period of eight months 19 patients were recruited for the study. There were 12 males and 7 females. Their age ranged from 21 to 69 years, with a mean of 39 years. The underlying pathology at the time of presentation was mainly trauma, seen in 11 patients, while others included degenerative disease, cancer and infections in the descending order (Table 1).

Underlying pathology	Number(19)	(%)
Trauma	11	57.9
Degenerative disease	6	31.5
Cancer	1	5.3
Infection	1	5.3

Table 1: Underlying Pathology requiring pedicle screw surgery.

In the 19 patients, one hundred and one screws were fixed. Sixty-seven screws were used in the 12 male patients while 34 screws were used in the 7 female patients. Most of the screws were fixed in the L1-L3 levels, 31out of 101(30.7%). Least fixed were the T7-T9 levels with 8 out of 101(7.9%) (Table 2).

Variable	T*(101)	M*(48)	I*(61)
Sex			
male	67	40	41
Female	34	8	20
		***p** = 0.061	***p**.0. 082
Age in (years)			
20-29	38	26	29
30-39	15	12	13
40-49	20	1	7
50-59	19	6	11
60-60	9	3	5
		***p** = 0.092	***p** = 0.099
Level of vertebra fixed			
T4-T6	10	2	4
T7-T9	7	3	3
T10-T12	24	18	19
L1-L3	31	20	19
L4-S1	29	5	16

Table 2: Distribution of number of screws fixed as per gender, age and level of vertebral spine.

Of the 101 pedicle screws inserted 24(23.8%) were centrally placed-(Figure 1),

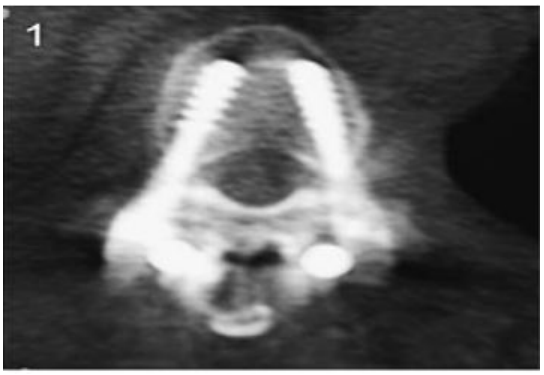

Figure 1: Centrally placed pedicle screws.

76(75.2%) were placed a little medial or inferior but within the confines of the pedicle cortices. Out of the 76, thirty-two (42.1%) were inserted both medial and inferior but within the pedicle, 29(38.2%) were inserted inferior but within the pedicle, whereas 15(19.7%) were inserted medial but within the pedicle. According to Youkilis et al. the 76 screws fall in either grade 1 or grade 2 violation but are within the confinements of the pedicle cortices and their position not dangerous. Only one screw (1%) was inserted with grade III medial cortical violation at T7 (Figure 2).

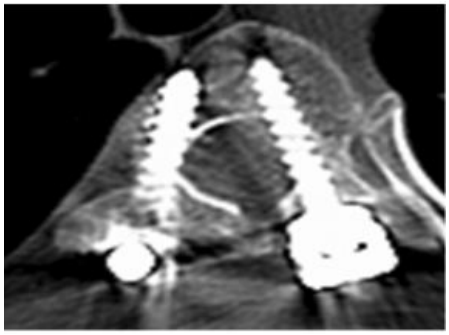

Figure 2: Screw violating the medial cortex and extending into the vertebral canal by 3.29mm.

This patient did not have neurological signs or cerebral spinal fluid leakage. A total of 48 screws were medially placed, 40 were inserted in male patients while 8 were inserted in female patients. This difference in sex as regards medial placement was not statistically significant, p = 0.061. Sixty-one screws were inferiorly placed, 41 inserted in male patients and 20 inserted in female patients. However, this difference was not statistically significant, p = 0.082. Majority of the screws were inserted in patients in age group 20-29 years, 38 out of 101 (37.6%). Additionally, the medial and inferior placement of the pedicle cortices were most prevalent in the same age group 26 out of 48 (54.2%) and 29 out of 61 (47.5%) respectively. The observed differences in medial and infe-

rior placement of the screws among the different age groups were not statistically significant, p = 0.092 and p = 0.099 respectively. Most of the screws were inserted in the L1-L3vertebral levels, 31 out of 101(30.7%). Out of these 20 had medial placement while 19 had inferior placement with in the pedicle (note that some screws had both medial and inferior placement) (table 2). Vertebral levels T7-T9 had the least number of screws inserted 7 out of 101(6.9%). Three of these were placed medially but within the pedicle while another three were placed inferiorly. The observed differences in the number of screws being placed either medially or inferiorly with in the pedicle among the different fixed spinal levels were not statistically significant, p = 0.677 and p = 0.164.

Key: T*(N) = Total number of screws inserted, M*(N) = Number of screws placed medially but within the pedicle, I*(N) = Number of screws placed inferiorly but within the pedicle, *p = the p value for the statistic test of the differentials in placement of the screw in the pedicle in different sexes, age and level of vertebra fixed.

Discussion

In this prospective case series, almost all screws were inserted within the confines of the pedicle cortices making the free hand method of pedicle screw fixation safe in the spinal unit at Mulago national referral hospital provided the correct anatomical landmarks are adhered to at the point of entry into the pedicle and the track to subsequently hold the screw is properly checked before insertion of the selected screw [13] have established that "Free-hand" technique for placement of pedicle instrumentation relies completely on the use of visible as well as palpable anatomic landmarks for accurate pedicle screw placement. It is dependent on a clear exposure and identification of the posterior elements' bony landmarks, including the lateral border of the pars interarticularis, the entire transverse process and the caudal and cephalad facet joints.

In one patient the inserted screw violated the medial cortex penetrating the spinal canal up to 3.29mm without causing any neurological damage. This can be explained by the inherent small pedicle diameter at this level. In the morphometric analysis of pedicle sizes by [14] it was demonstrated that the smallest pedicle diameters are between vertebral bodies T4 and T7 with a minimum of 3.7 mm at T5 level, whereas [15] revealed that generally, the diameters increase in the caudad direction from the thoracic to the lumbar spine. In a systematic review of prospective in vivo studies comparing free hand, fluoroscopy guided and navigation techniques [11], it was noted that in free hand technique the accuracy rates range from 69-94%, in Fluoroscopy guided it ranges from 28-85%, while with CT- navigated it ranges from89-100% and yet with Fluoroscopy based navigation it range from 81- 92%. The screw positioning with free hand technique tend to perforate the medial cortex whereas the screws placed with CT navigated guidance tend to perforate laterally [11].

This study has shown that age and sex do not influence the accurate insertion of pedicle screws by the free hand technique [16] in their work on 2,201 pedicle screws inserted in 116 patients with adolescent idiopathic scoliosis found that sex and gender differences did not influence the accuracy of pedicle screw insertion. In contrast to the normal orientation of the pedicles in our patients, whose pathologies were mainly trauma and degenerative diseases of the spine, Kasim and Acke analyzed accuracy of pedicle insertion in a patient population whose pedicles are inherently rotated depending on the extent of rotational deformity that accompanies scoliosis as has been pointed out [17]. This implies that as long as the surgeon is experienced with the free hand technique and the entry point is properly selected, the age and sex of the patient will not affect the proper insertion of the pedicle screw.

In this study it was statistically found that the level of vertebra fixed did not influence the accuracy of insertion of the pedicle screw. However, it is biologically plausible for the surgeon to remember the anatomical differences in the pedicle diameters (narrowest at T4-T7) at the time of insertion. This was revealed by the one screw that violated the medial cortex at T7. In a related study [18] it was revealed that successful placement of screws within the pedicle varies with the anatomic diameter of the pedicle itself. Additionally, they pointed out that concerns regarding accuracy of screw placement should be greatest in the middle thoracic vertebrae (T4-T7), where pedicle diameters are smallest and proximity of the great vessels is nearest. In conclusion and based on the case series studied, First, posterior spine instrumentation by pedicle screws and rod can be safely inserted in the spine ward of Mulago hospital as long as the procedure is performed observing the whole anatomy of the spine. Secondly, the studied demographic factors-sex, age and level of vertebra fixed - do not influence the accuracy of the pedicle screw insertion by the free hand technique. The content of this article is the sole work of the authors. No benefits of any form have been received or will be received from any commercial party related directly or indirectly to the subject of this article.

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