ORIGINAL ARTICLE

Usefulness of navigated O-arm® in a teaching center for spinal trauma

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ABSTRACT

Background: There is a relatively high incidence of screw misplacement during spinal instrumentation due to distortion of normal anatomy following spinal trauma.

Aims and Objectives: To evaluate and share the initial experience with the use of neuro-navigated 3D O-arm® (Medtronic, USA) as compared to traditional 2D fluoroscopy in atrauma center in India.

Materials and Methods: In this retrospective study, consecutive patients of spinal injury who underwent screw fixation under O-arm guidance over nine-month period (July 2010 till March 2011) were evaluated for accuracy of screw placement. An equal number of consecutive patients prior to March 2011 who underwent screw fixation in 2D fluoroscopy were included for comparison. Patient demographics and radiology were reviewed and spinal injury was assessed using the ASIA grading in both the groups. Screw placement was assessed by postoperative CT scans of the relevant spine and accuracy of screw placement and breach of the medial or lateral cortex of the pedicle were recorded for each case.

Results: In the O-arm group, there were 57 patients in whom 210 screws were inserted. None of the patients had screw mal-placement. In 2D fluoroscopy group, 57 patients had 268 screws insertions. 10 (3.73%) screws were found to be malpositioned in the postoperative CT scans (8 in thoracic spine and 2 in odontoid fractures). The malposition rate was highly significant in 2D fluoroscopy thoracolumbar ($P = 0.0015$) subgroup. One patient had neurological deterioration and three patients required repositioning of the screws. **Conclusion:** In a teaching center with multiple surgeons, the O-armâ imaging ensures accurate placement of screws as compared to traditional 2D fluoroscopy.

Key words: 3D intraoperative imaging, complication, O-arm, screw, spine, trauma

Introduction

In the past decade, pedicle screw fixation of the spine has gained greater acceptance as a result of improved instrumentation and consequently better clinical outcome. Nevertheless, accuracy of screw placement remains a concern, especially in training institutes where expertise in screw placement may not be available with all surgeons.[1] At present, 2D fluoroscopy is commonly employed for intraoperative anatomical orientation of screw placement.[2] Intraoperative fluoroscopy and serial radiography only demonstrate the depth of screw penetration but cannot be used to recognize screw malpositioning. Intraoperative radiographic observation of screw tips that have been placed too close or too far from each other might only suggest a possible misplaced screw. Unfortunately, these suspect screws can only be observed to be penetrating the medial or lateral cortex of the pedicle on postoperative CT scans.

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Complications of spinal instrumentation placement can be serious and include vascular, visceral, and neurological injury.[3-5]

The O-arm imaging system provides complete multi-dimensional surgical imaging and neuronavigation in a seamless manner and provides surgeons with real-time, 3D images, as well as multi-plane, 2D and fluoroscopic imaging. The system was installed at our center in July 2010. Since then we have used the system on 57 patients. In this study, we attempted to assess the usefulness of O-arm compared to the standard 2D fluoroscopy available.

Materials and Methods

In this retrospective study, consecutive patients of spinal injury who underwent posterior or anterior screw fixation under O-arm guidance over nine-month period (July 2010 to March 2011) at JPNATC, AIIMS, were evaluated for accuracy of screw placement in the postoperative period.

An equal number of consecutive patients from January 2010 to March 2011 who underwent screw fixation in 2D fluoroscopy were included for comparison. Patient demographic, clinical findings and radiology were reviewed, and spinal injury was assessed using the ASIA grading in all cases.

Procedure Under O-arm

Briefly, the O-arm procedure consists of acquiring a 3D data set of images with a reference frame attached to the spinous process one level higher or lower to the operative field. After acquisition of the images, navigation accuracy was confirmed by touching anatomical landmarks with the image-guided probe. The intraoperative planning function on the image-guided system, which places a phantom screw on the tip of the probe, was then used to ascertain the entry point and trajectory of the screw. The optimal length and diameter of the screw were also determined using this function; and it should be noted that in each case, effort was made to place the maximum diameter screw that the anatomy could accommodate. After the pedicle was either probed or drilled under image guidance, a pedicle feeler was then used to confirm that there was no pedicle breach, and the hole was then tapped in the same trajectory and the screw placed. Navigation accuracy was briefly checked again prior to placement of the next screw by touching anatomical landmarks. Following surgery, 3D CT was performed using the O-arm inside the operating room in all patients to assess accuracy of screw placement and breach of the medial or lateral cortex of the pedicle.

The comparison group underwent screw placement under standard 2D fluoroscopy. All patients underwent CT spine (at the relevant level) in the postoperative period.

Screw placement was assessed by postoperative CT scans of the relevant spine and accuracy of screw placement and breach of the medial or lateral cortex of the pedicle were recorded for each case.

Statistical analysis was done using graph pad statistical tool (www.graphpad.com). Fisher exact Chi-square test was used to see for significance between the groups.

Results

O-arm group

There were 57 patients in this group of which 47 patients (82.5%) were males and 10 patients (17.5%) were females. 23 patients (40.3%) had road traffic accidents leading to spinal trauma whereas 33 patients (58%) had history of fall and 1 (1.7%) patients had history of assault preceding spinal injury. The mean age of the patients was 29.88 years (range 7-62 years).

Of the 16 patients with cervical spine injuries, six patients (10.5%) had odontoid fracture and 10 (17.5%) had subaxial cervical spine injuries. 41 patients (72%) had thoracolumbar fractures.

The spinal injuries were graded as per ASIA grading system and five different subsets were formed (A-E). 19 patients (33.3%) had ASIA grade A injuries whereas 15 patients (26%) had grade B, 10 patients (17.5%) had grade C, 6 patients (10.5%) had grade D and 7 (12.3%) had grade E injuries [Table 1].

A total of 210 screws were inserted under O-arm guidance. Out of these, 168 (80%) were thoracolumbar pedicle screws, 6 (3%) were odontoid screws, 36 (17%) subaxial cervical (lateral mass) screws [Table 2]. None of the patients had screw mal-placement or canal breach and none required procedure reoperation. No patient had postoperative neurological deterioration. The system was rated as excellent for ease of use by all faculties using the system.

Standard 2D fluoroscopy group

Similar to the O-arm group, 57 consecutive patients were taken in this group, of which 48 patients (84.2%) were males and 9 patients (15.8%) were females. 22 patients (38.6%) had road traffic accidents leading to spinal trauma whereas 34 patients (59.6%) had history of fall and 1 (1.7%) patient had history of assault preceding spinal injury. Mean age of the patients was 32.4 years (range 4-80 years).

Of the 36 patients with cervical spine injuries 4 patients (7%) had odontoid fracture, and 32 patients (56%) had subaxial cervical spine injuries. Another 21 patients (37%) had thoracolumbar fractures. Patients' injuries were similarly graded as per ASIA grading system [Table 2]. 18 patients (31.6%) had ASIA grade A injuries whereas 18 patients (31.6%) had grade B, 9 patients (16%) had grade C, 4 patients (7%) had grade D and 7 (12.4%) had grade E injuries [Table 1].

A total of 268 screws were inserted under standard fluoroscopic guidance. Out of these, 138 (51.5%) were thoracolumbar pedicle screws, 4 (1.5%) were odontoid screws and 126 (47%) subaxial cervical (lateral mass) screws [Table 2].

Of these 10 (1.5%) screws were malpositioned (8 in thoracic spine and 2 in odontoid fractures).

The malposition rate was highly significant in 2D fluoroscopy thoracolumbar ($P = 0.0015$) subgroup but not in other subgroups. Amongst the thoracic screws which were malpositioned, there was breach in the medial wall of the

Table 1: The demographics of O-arm and standard fluoroscopy groups

	O-arm group		Standard (2D) fluoroscopy group	
	Number	Percentage	Number	Percentage
Total number of patients	57		57	
Patients with cervical injury				
Total patients	16	28	36	63
Odontoid fracture	6	10.5	4	7
Subaxial cervical spine fractures	10	17.5	32	56
Patients with thoracolumbar injury	41	72	21	37
Asia grade				
A	19	33.3	18	31.6
B	15	26	18	31.6
C	10	17.5	9	16
D	7	12.3	4	7
E	7	12.3	7	12.4
Males	47	82.5	48	84.2
Females	10	17.5	9	15.8
Mean age	29.9		32.4	

Table 2: The screw characteristics of O-arm and standard fluoroscopy groups

	O-arm group		Standard (2D) fluoroscopy group	
	Number	Percentage	Number	Percentage
Total number of screws placed	210			
Cervical screws				
Total	42	20	130	48.5
Odontoid screws placed	6	3	4	1.5
Odontoid screws malpositioned	0		2	50
Cervical lateral mass screws	36	17	126	47
Cervical lateral mass screws malpositioned	0		0	
Thoracolumbar screws				
Total placed	168	80	138	51.5
Medial cortex breach	0		7	5
Lateral cortex breach	0		1	0.7

pedicle in seven screws and breach in the lateral wall in one screw. In both patients with odontoid fracture with malpositioned screw, the screw was found to be going posteriorly without proper purchase of the fractured odontoid tip. One patient had neurological deterioration postoperative period. Three patients (all having screw misplacement in the thoracic spine) underwent re-exploration and screw repositioning was done under O-arm guidance.

Discussion

Image-guidance techniques began to be implemented in spinal surgery procedures in 1995 and have been designed to increase the accuracy of spinal instrumentation placement.[4-6] Standard techniques of pedicle screws insertion have included fluoroscopic guidance, as well as the freehand technique. A 14-55% misplacement rate for pedicle screws using standard techniques has been reported.[7] Additionally, injury from pedicle screws placement has been reported to occur at a rate of 1-8%.[8] In a meta-analysis of the published literature on accuracy of pedicle screws placement, Kosmopoulos and Schizas[9] reported a median accuracy of 90.3% in 12,299 pedicle screws placed *in vivo* without navigation versus a median accuracy of 95.2% in 3059 pedicle screws placed *in vivo* with navigation. This meta-analysis did not include studies published after 2006 and also did not specify navigation techniques. Since this time, several studies have been published reporting accuracy of pedicle screws placement with the aid of 3D navigation.

Spinal injuries are surgically more challenging as there is distortion of anatomy making visualization of the screw trajectory difficult even for experienced surgeons. In a randomized clinical trial comparing thoracic pedicle screws placement using fluoroscopic assistance versus 3D fluoroscopy-based navigation in patients with spinal deformity, Rajasekaran *et al.*[10] found a 23% breach rate in the fluoroscopic group compared with a 2% breach rate in the navigation group. Nottmeier *et al.*[11] reviewed 220 consecutive patients undergoing posterior spinal fusion using 3D image guidance for instrumentation placement and noted a breach rate of 7.5%. No vascular or visceral complications occurred as a result of screw placement. Two nerve root injuries occurred in 1084 screws placed, resulting in a 0.2% per screw incidence and a 0.9% patient incidence of nerve root injury. In teaching institutes with residency programs, a number of surgeons with variable skill set are present. The important issue is to teach a novice surgeon with the complexities of spinal trauma without compromising patient safety. Although simulation exercises are helpful on saw-bone models, they cannot substitute for the learning curve in the real world setting. An O-arm seems as an ideal alternative in such cases, as it allows the surgeon to place his probe according to his perceived trajectory and compare with the O-arm navigated trajectory, thus improving his operative skills without compromising on patient safety. The flip side to this system is that one may tend to become complacent and dependent on the O-arm for deciding screw trajectory. It has to be remembered that the O-arm is only a tool and cannot substitute for a surgeon's skill or experience. One of our initial doubts on using O-arm was whether it would be difficult to set up and use. All faculties using it at our center have been unanimous regarding its ease in setting up and usefulness in spinal trauma cases. We use the O-arm with neuronavigation and microscope routine in odontoid screw fixations and in thoracolumbar fractures [Figures 1 and 2]. The integrated neuro-navigation system is also

Figure 1: Photograph showing O-arm with neuronavigation being used for odontoid screw placement

Figure 2: Photograph showing simultaneous use of microscope and O-arm in a patient with thoracolumbar fracture

very easy to use. Although, there is an option of using optical-guided or electromagnetic tracking of instruments, we have been using optical tracking as it is economically much cheaper. The use of optical tracking of instruments has a potential disadvantage of requiring line-of-sight between the system camera and the neuro-navigated instrument.[12] However, when properly set up, we have not really found this to be an issue.

In spite of having larger number of patients who underwent cervical procedures in the standard fluoroscopy group, the number of thoracolumbar screws placed is similar in both the groups. This reflects the initial unease in use of O-arm when some surgeons continued to use the standard fluoroscopy for spinal crew fixations. However, currently all neurosurgeons in the department use it routinely for spinal instrumentation.

Radiation exposure to the surgeon and operating room staff is a concern when placing instrumentation with the aid of active fluoroscopy.[13] Accordingly, the reported fluoroscopy time used to place one pedicle screws varies in the literature from 3.4 to 66 s per screw.[14,15] Another ways that O-arm scores over standard fluoroscopy is in dramatically minimizing radiation exposure to the operating room staff. It is no longer necessary to wear lead aprons while operating under O-arm guidance. Only one set of images is required to be acquired by the O-arm (which takes approximately 13 s) during which the staff vacate the room or stand behind a lead shield. The rest of the surgery is done under neuronavigation from the images thus acquired.

As the O-arm is akin to a CT machine, it is possible to take high quality 3D CT of the affected spine postoperatively inside the OT, thus confirming the correct placement of the implants.

Drawbacks of the study

We included patients who underwent both cervical (odontoid and lateral mass) and thoracolumbar screw fixation in this study. As would be expected, higher number of cervical procedures was done under standard fluoroscopy. We however wanted to avoid bias in case of selection and therefore included consecutive cases in both the groups.

Conclusions

In our study we could dramatically decrease the complication rate in screw malpositioning and re-operations by the use of O-arm. Its use is especially beneficial in academic and teaching centers where novice surgeons can attain results equivalent to that of experts in spinal instrumentation with consistent results and without compromising on patient safety.

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