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Evaluating the accuracy of screw placement using intraoperative computed tomography with navigation in dorsal and lumbo-sacral spine fixation surgery

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Abstract

Objective: To evaluate accuracy of screw placement using intra-operative Computed Tomography with navigation in dorsal and lumbosacral spine fixation surgery.
Patients and Methods: The study included 20 patients operated in Tanta University Hospital and Al Galaa Military Hospital in Cairo in the period from September 2018 to July 2022, all of them were having spinal instability of their thoracic, thoracolumbar, lumbar and lumbosacral spine with a male to female ratio 4:1.
Results: While using Airo lowers the breach rate of transpedicular screws and prevents major intraoperative complications such vascular, visceral, and neurological injury, it does not completely remove the risk of mispositioning. Enough decompression of the cord, thecal sac, and nerve roots was accomplished. However, a number of traps, such as reference frame mobilization, spine motion between the frame and the instrumented vertebrae, and associated technological faults, can lower navigation accuracy and result in screw malplacement. Airo requires a spacious operating room and a skilled surgical team, and it is more expensive than traditional methods.
Conclusion: Intraoperative CT with navigation reduces screw malplacement and if there is intraoperative malplacement this could be corrected immediately and consequently prohibit the need of correction surgery. CT with navigation facilitate fixation surgery in obese patients due to good quality of images also it reduces breach rate. CT with navigation facilitate fixation in thoracic spine as the pedicle is small with complex 3D anatomy. It gives information about adequate cord, thecal sac and nerve roots decompression during surgery. So intraoperative CT with navigation provide easier surgery, greater accuracy, less complications and consequently improves outcome. It declines radiation exposure to surgical team. On the other hand, still cost, wide operating theatre, well trained team and intraoperative technical errors represent challenges.

Keywords: Lumbo-sacral spine, transpedicular screws, spine motion, surgery

Introduction

Since King's 1948 [1] description of the use of screws for spinal fixation, a number of methods and systems have been developed and are now commonly utilized for thoracolumbar spine fixation [2]. Screw placement has been guided and verified using a variety of ways [3]. Anatomic landmarks [4], laminotomy for pedicle palpation, plain radiography, fluoroscopic imaging (standard or image guidance) [5], and CT image guidance [6] are a few examples of these methods.

Proper screw placement is vital in order to avoid complication such as CSF leak, vascular, visceral, and neurologic injury; however, screw malposition is a more common complication, with a cited incidence of 0-42% [7-8]. Proper screw placement provides good fixation so it minimizes screw pullout, breakage, and late spinal instability [9]. The safety and accuracy of pedicle screw insertion have been improved by technological advancements, including navigation [8]. Spine surgeons expressed a strong desire for this technology, believing that navigation would be particularly helpful for placing spinal implants in cases when direct visualization was not possible [10].

Intraoperative navigation techniques have advanced since the 1990s [11]. One of the newest intraoperative imaging systems, CT navigation, has gained widespread recognition for its superiority [12-13].

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According to a publication [12], the percentage of pedicle perforations drops from 15% in non-navigated screws to 6% in navigated pedicle screw insertions. Conversely, mishaps during navigation may ultimately result in surgical time loss, extended anesthesia, and intraoperative pedicle screw mistakes. Inadequate pre- and intraoperative planning will reduce the navigation system's effectiveness [13].

Additionally, as minimally invasive surgical procedures for spine surgery became more common, doctors tried to undertake larger surgeries with fewer exposed bone areas and smaller skin incisions. Because of the clear benefits of intraoperative navigation during these procedures, driven spine surgeons began modifying and using the technology in order to assess its effectiveness in these kinds of treatments. [14].

Aim of the work

To evaluate accuracy of screw placement using intra-operative Computed Tomography with navigation in dorsal and lumbosacral spine fixation surgery.

Patients and Methods

This study was focused on the operative data collected from the operations have been done on total of twenty-three (23) patients with dorsolumber spine pathology; six of them were having fracture thoracolumbar junction, five cases were having multilevel lumber stenosis, one was having Pott's disease of upper thoracic spine and eleven cases were having degenerative lumbosacral spondylolisthesis, all cases subjected to posterior transpedicular screw fixation according to pathological level under general anaesthesia.

The study has been done by the department of Neurosurgery of Tanta university hospitals and department of Neurosurgery of Al Galaa Military Hospital in Cairo, to evaluate the value of using the assistance of intraoperative CT with Navigation (AIRO) in such procedures done in the period starting from September 2018 till July 2022. The patient selection for the study has been done according to the following criteria;

Inclusion criteria: Gender: both sexes. Minimum age: 18 Years. Type of Pathology: Patients with unstable spine for any cause (pathological, traumatic, and degenerative). Level of the pathology: patient with thoracic, thoracolumbar, lumbar and lumbosacral pathology.

Exclusion criteria: Patients with associated cervical pathology that needs surgery. Poly-traumatized patient who has other pathology that interfere with fixation surgery (either interfere with general anesthesia or prone position). Patient who are unfit for surgery due to bad general condition.

Dropouts: Because of computer hardware or software errors, the operation has been converted from computer-assisted surgery to conventional techniques in three patients who has been statistically removed from the study.

Patients were subjected to the following

Clinical Assessment: Personal data: Name, Age, Sex, Occupation, Marital status and Special habits. Complaint: It included one or more of the following: Back pain, Radicular pain, neurogenic claudication, motor deficits, sensory deficits and visceral troubles. Present history: analysis of the complaint as regards; mode of onset, duration, course of illness (progressive, regressive or stationary), treatment received and the response to treatment. Since good history taking is considered an important step in establishing the diagnosis of spine pathology, some leading questions were asked to the patient to satisfy all the aspects related to his symptoms, these questions include the following: Back pain: site, character, radiation, aggravating and relieving factors. Leg pain: site, character, aggravating and relieving factors, associated symptoms (weakness, parasthesia). Past history: History of trauma, chronic diseases like diabetes, hypertension, and previous operations. Family history: History of similar illness, diabetes or TB. Clinical Examination: The clinical examination is subdivided into 2 main aspects, general examination & neurological examination. General examination; It included assessment of the vital signs, chest, heart, abdomen, and assessment of peripheral circulation (arterial pulsation, signs of ischemia e.g., dry skin, loss of hair and brittleness of nails) Neurological examination; Motor system: degree of motor power and the distribution of weakness if present. Sensory system: to look for hypoesthesia and its distribution. Reflexes: to look for diminished, exaggerated or absent reflexes. Nerve root tension signs. Examination of the back: to look for tenderness, paravertebral muscle spasm, limitation of back movement, deformity.

Investigations: Routine laboratory work up: including complete blood picture, blood sugar level, liver function tests, blood urea and creatinine, bleeding and coagulation times. Neuroimaging studies: the following imaging studies were done to the patients of the study preoperatively; Plain x-ray to specific part of the spine, done to identify various congenital anomalies e.g., Spina bifida occulta, evidences of degenerative bony changes including osteophytes, evidences of spinal instability (dynamic view), spondylolisthesis & pars fracture (oblique view). CT spine which is more sensitive tool in the diagnosis of all bony lesions. MRI spine, it provides detailed images of disc herniation, narrowing of the dural sac, narrowing of the nerve root canal, status of the ligamentum flavum & condition of the facet joint when T2 weighted sagittal & axial pulse sequences were used. DEXA scan (bone densitometry) especially for females and patients suspected to have osteoporosis due to any medical condition [15].

Surgery

General setup of the AIRO during navigated spinal Instrumentation

We employed the mobile AIRO CT scanner for spinal navigation based on intraoperative CT (BrainLab AG, Feldkirchen, Germany). This system is made to work in an operating room and includes a movable CT gantry (diameter 107 cm; dimensions 30.5 cm 9 38 cm) that holds the battery pack, high-voltage generator, air cooling system, and 32-slice helical scan detector array in addition to the X-ray tube. The AIRO can perform CT scanning and is operated by a detachable portable touchpad. One person can move the AIRO from one location to another thanks to a suspension-controlled electrical drive system.

Additionally, we made use of a carbon fiber CT examination table that is transportable and radiolucent and is mounted to the gantry during operation. The AIRO is equipped with an infrared tracking camera (BrainLab Curve TM, BrainLab

AG, Feldkirchen, Germany) and an image-guidance system for navigation, allowing for automatic picture transfer and image-patient co-registration.

Workflow of Total Navigation with the Airo System

Every patient was given written and informed consent that included information about the surgery, the risks associated with the CT scan protocol, and more. Every patient was placed under general anesthesia. The patient is placed prone on the radiolucent table, which is angled in relation to the Airo CT scanner, following intubation. Every cable, including the suction, Bovie, and intubation tube, is positioned so that the leads pass through the Airo's gantry. In order to guarantee immobilization and improve navigation accuracy, the patient is taped to the table.

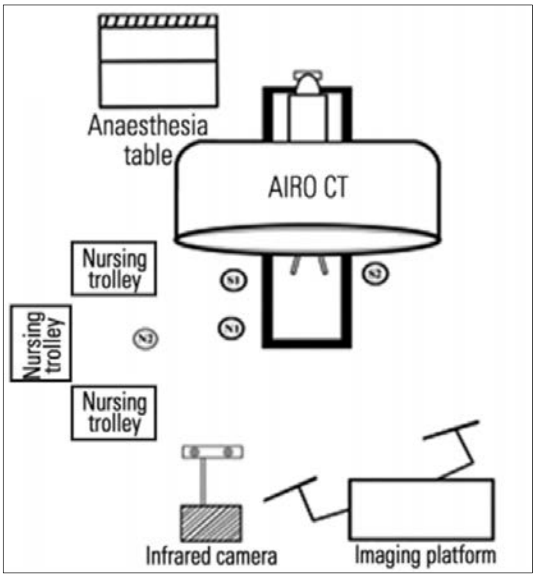


Fig 1: Schematic of the OR setup for navigated spinal instrumentation with the mobile AIRO CT [16].

To determine the proper incision site of the level to be exposed, a pre-incision lateral radiograph is sufficient, together with the placement of a radio-opaque skin marker in accordance with the anatomic landmark. To reveal the spine, a posterior midline incision was made. On both sides of the midline, the paraspinal muscles were raised to the tip of the transverse processes of the vertebrae that needed to be operated on. A reference array, or navigation tracking device, was clamped cranially or caudally to the levels of instrumentation at one or two spinous processes.

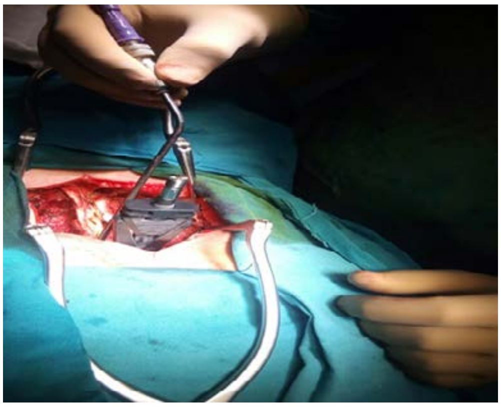
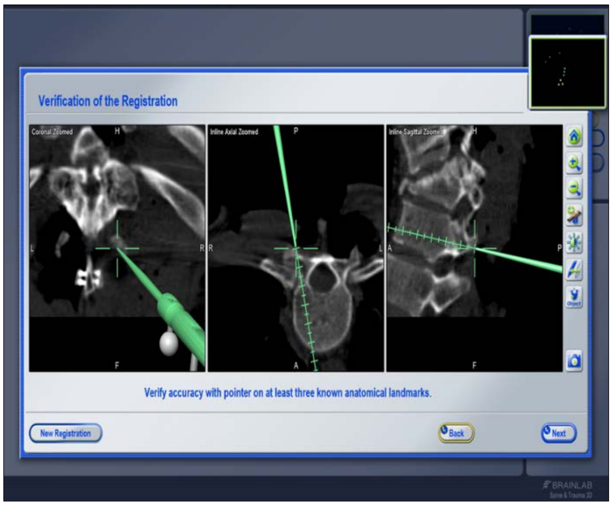


Fig 2: Reference array was clamped 1–2 spinous processes cranial to the levels of instrumentation

Intraoperative CT scanning

When the scanning is ready to start, everyone leaves the operating room, including the radiology technologist who takes the Airo touch screen outside the door to operate the scan. Thus, neither the surgeon nor the surgical staff need to wear a lead apron. Laser guiding is used to help program the scan region. After the scan is finished, the images are automatically sent to the BrainLab Spinal Navigation software intraoperative image-guidance platform to produce 3D CT images. The tracking device's co-registration is enabled by adjusting the navigation camera. Next, by lining up the navigation probe or pointer over recognized anatomical landmarks such the spinous process, transverse process, or lamina, the accuracy of the navigation is verified. It is verified that the probe placement in the workstation's virtual images corresponds to the surface anatomy. Moreover, the probe can be tracked in real time by dragging the cursor along the lamina's exterior. The discrepancy between the virtual and actual placements suggests a problem with the registration procedure and calls for a new registration.



Verify accuracy with pointer on at least three known anatomical landmarks.

Fig 3: Verification of registration

Pedicle Screw Insertion Using Navigation

The electrooptical camera was positioned 1.5 meters from the patient's foot end at the caudal end of the operating table. Infrared reflecting gleons attached to the various equipment reflected back infrared rays sent by the electrooptical camera system. The computer workstation's reception of the reflected infrared rays demonstrates how the patient's body's several instruments are synchronized.

The imaging workstation shows images in sagittal, coronal, and axial planes when the navigation pointer is positioned perpendicular to the spine's longitudinal axis. The surgeon can see the three-dimensional spinal anatomy, which is invisible to the unaided eye, thanks to reformatted images that alter based on the angle and direction of the probe. The surgical instruments were calibrated. Placing the probe correctly allows one to identify the proper entrance point and angulation for the screw trajectory. Furthermore, overlaid pictures at the planned level are used to establish the screw dimension to be placed. Every stage of pedicle screw instrumentation is carried out using specialized instruments with passive arrays and navigation guidance. Finally, a screw with the proper size is put into the trajectory that has been made.

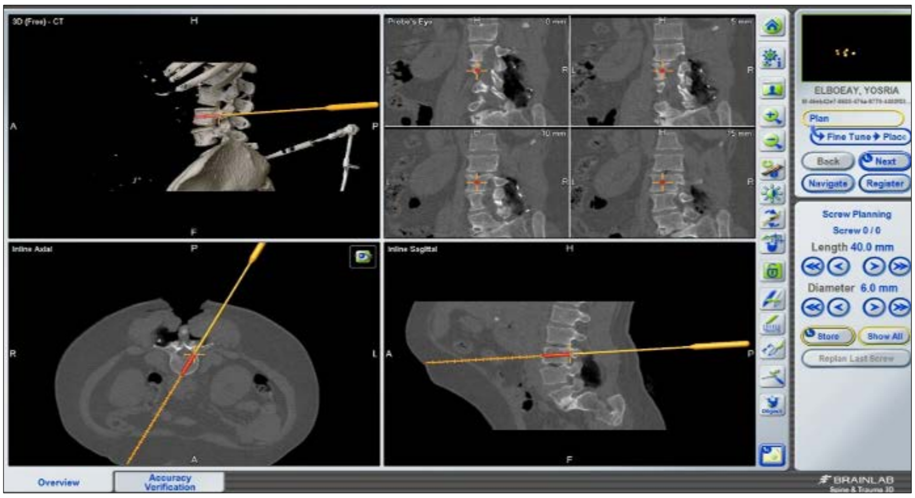


Fig 4 A: Pedicle Screw Insertion Using Navigation

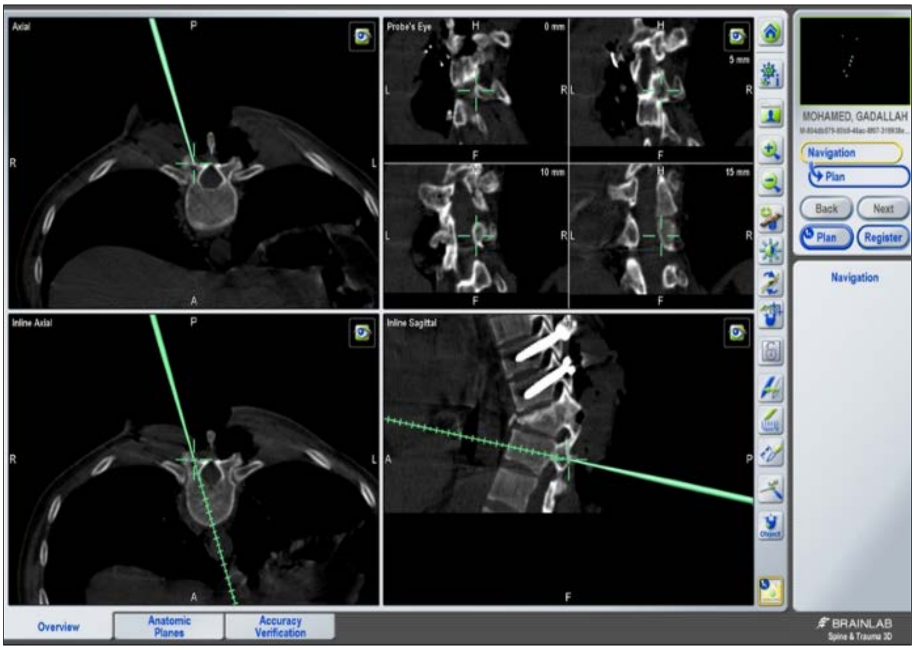


Fig 4 B: Pedicle Screw Insertion Using Navigation

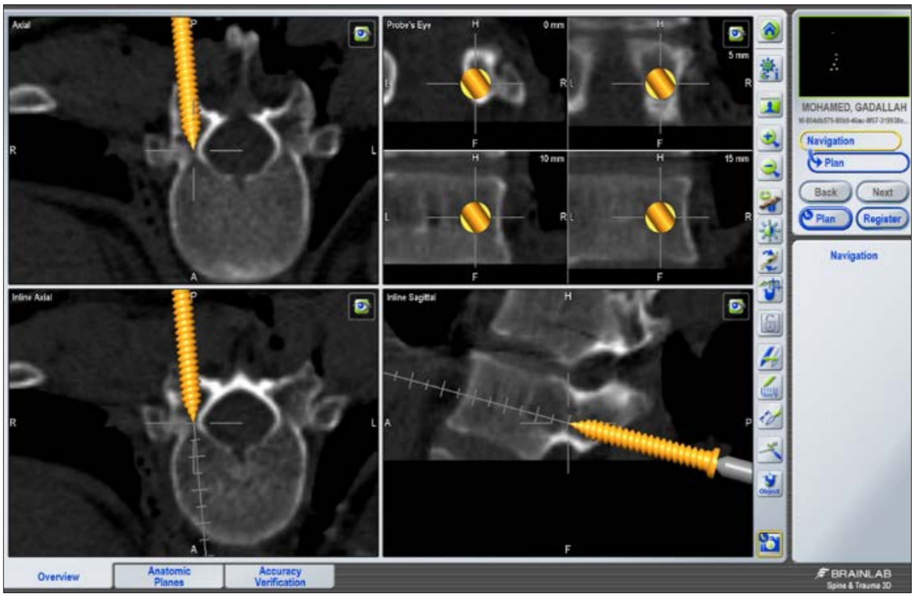


Fig 4 C: Pedicle Screw Insertion Using Navigation

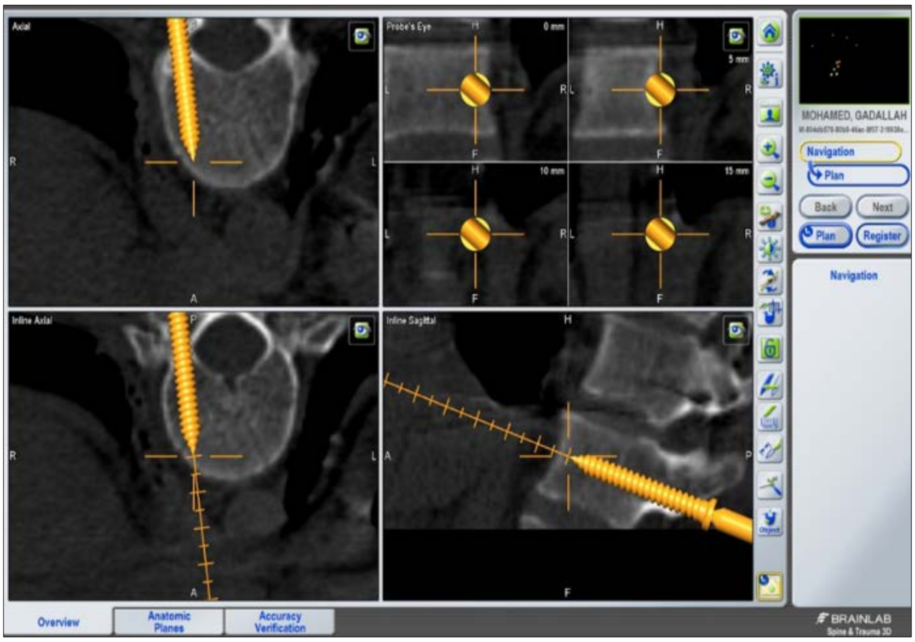


Fig 4 D: Pedicle Screw Insertion Using Navigation

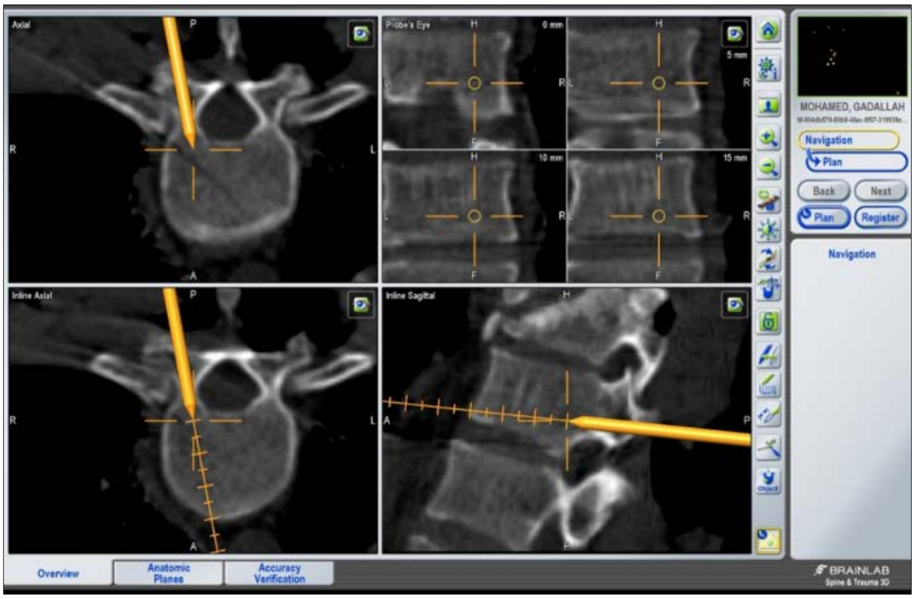


Fig 4 E: Pedicle Screw Insertion Using Navigation

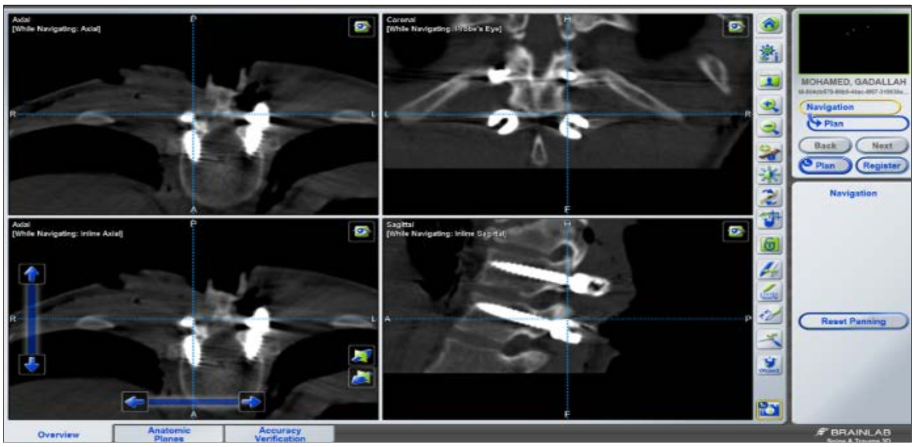


Fig 4 F: Pedicle Screw Insertion Using Navigation

Each screw's actual insertion time as well as the time needed for registration and matching were recorded. Intraoperatively, the Airo 3D pictures were acquired following the insertion of the screws. A CT image of the operated spine was performed immediately after surgery, displaying the screws' locations in all three planes. To find any breaches in the pedicle walls, the position of each screw was examined.

Evaluation of workflow and screw position

The duration of the screw insertion, or the time from the end of the spine's exposure to the insertion of every screw, was measured for every patient. Additionally, the times needed for setting up and carrying out the intraoperative CT were measured for each treatment. This involved checking the instrument's calibration, fixing the dynamic reference base to the vertebra, matching, confirming the correctness, getting the screw tracks ready, and inserting the screws. Both the length of the operation and any intraoperative problems were noted. A second intraoperative CT scan was used to examine every screw.

The screw position was then graded according to Gertzbein-Robbins classification [17].

Table 1: Gertzbein-Robbins classification

Grade A	An intrapedicular screw without breach of the cortical layer of the pedicle;
Grade B	A screw that breaches the cortical layer of the pedicle but does not exceed it laterally by more than 2 mm;
Grade C	Penetration of less than 4mm.
Grade D	Penetration of more than 4 but less than 6 mm.
Grade E	Screws (arrows) that do not pass through the pedicle or that, at any given point in their intended intrapedicular course, breach the cortical layer of the pedicle in any direction by more than 6 mm.

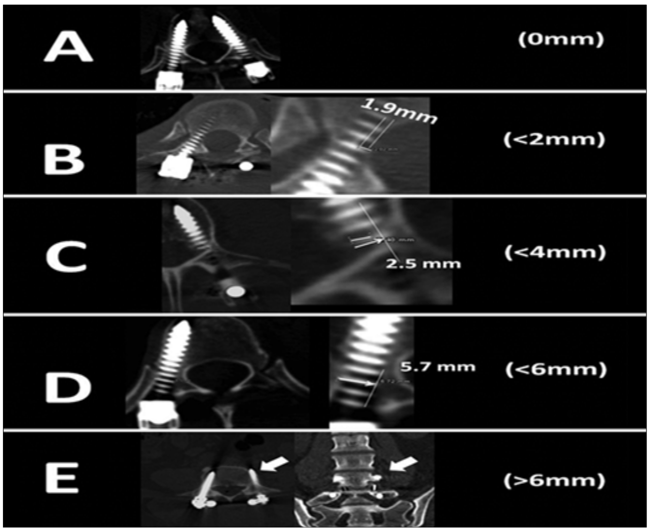


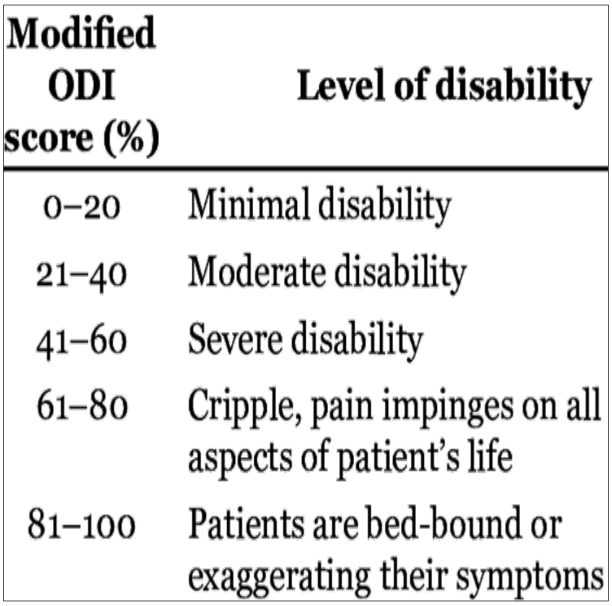
Fig 5: Gertzbein-Robbins classification

The primary goal was to ascertain the screw accuracy rate, which we did by calculating the proportion of screws that were either entirely inside the pedicle, had small pedicle perforations (less than 2 mm), or were misaligned (more than 2mm).

Clinical outcome

Functionality was assessed using the Oswestry Disability Index (ODI), which was used to evaluate back pain and disability. Ten elements made up the ODI, and each item had a score between 0 and 50; greater scores denoted worse condition. At the time of admission and one month following surgery, the ODI score was assessed. A 30 percent or more improvement from the baseline in the ODI score was considered surgical success [18].

The total score is five for each part of six statements; if the first statement is marked, the score is zero; if the last statement is marked, the score is five. Statements that intervene are ranked and given a score. Choose the highest score if more than one box is checked in each section. The following formula is used to determine the score if all ten portions are finished: For instance, 16 is the total score out of 50 available points, or 32 percent. The following formula is used to determine the score if a section is missed or not applicable: For instance, 16 is the total score and 45 is the total possible score. × 100 = 35.6%. In terms of disability, a low score corresponds to a low degree and a high score to a high degree.



Modified ODI score (%)	Level of disability
0–20	Minimal disability
21–40	Moderate disability
41–60	Severe disability
61–80	Cripple, pain impinges on all aspects of patient's life
81–100	Patients are bed-bound or exaggerating their symptoms

Oswestry Disability Index (English and Arabic Versions) Results

After exclusion of the dropouts, in this study, 130 pedicle screws were placed in 20 patients who were admitted to Tanta University hospital and Algalaa military hospital in the period from September 2018 to July 2022.

Table 2: Percentage Distribution of cases according to age & sex.

Age groups	Male		Female		Total	
	No.	%	No.	%	No.	%
20-30	3	15	2	10	5	25
31-40	2	10	1	5	3	15
41-50	1	5	4	20	5	25
51-60	3	15	4	20	7	35
Total	9	45	11	55	20	100

Table 3: Distribution of patients according to pathology and indication for fixation.

Pathology	Number of patients	Percentage
Pott's Disease	1	5
Unstable thoraco lumber fracture	6	33.33
Degenerative spondylolisthesis	9	45
Long segment canal stenosis	4	20
Total	20	100

Table 4: Percentage Distribution of cases according to clinical presentation of the Disease.

Symptoms	Number of patients	incidence
Back Pain	20	100
Radiculopathy	3	15
Radiculopathy and Neurogenic Claudication	8	40
Numbness	12	60
urinary incontinence	4	20
Sense of weakness	10	50

Table 5: Percentage Distribution of cases according to Presence of Motor, Sensory or Visceral Deficits.

Deficits	Number of patients	incidence
weakness	9	45
Sensory	15	75
Visceral	4	20
Non	1	5

Table 6: Distribution of cases according to the level of spinal pathology.

Level of pathology	Number of patients	Percentage
Upper Thoracic	1	5
Thoracolumbar junction	6	33.33
lumber	3	15
Lumbosacral	10	50
Total	20	100

Table 7: Percentage Distribution of screws according to the level of spinal insertion.

Level of screw insertion	Number of screws	Percentage
Thoracic 1	2	1.54
Thoracic 2	2	1.54
Thoracic 5	2	1.54
Thoracic 6	2	1.54
Thoracic 9	2	1.54
Thoracic 10	6	4.62
Thoracic 11	10	7.69
Thoracic 12	8	6.15
Lumber 1	6	4.62
Lumber 2	12	9.23
Lumber 3	14	10.77
Lumber 4	18	13.84
Lumber 5	26	20
Sacral 1	20	15.38
Total	130	100

Table 8: Percentage of Pedicle screw characteristics according to inserted vertebra.

Level of screw insertion	Screw Diameter (mm)	Screw Length (mm)
Thoracic 1 - 2	4.5 mm	25 mm
Thoracic 5 - 6	3.5 - 4.5	30-35
Thoracic 9 -12	5.5 - 6.5	35-40
Lumber 1-4	5.5 - 6.5	40-45
Lumber 5	5.5 - 6.5	45-50
Sacral 1	4.5 - 5	35-40

Table 9: The Mean time of each step during the procedure.

Steps in Order	Time (Min)	Mean (Min)
Positioning of the Airo	3-10	6.5
Setup of the image-guidance system	2-6	4
Surgical prep-time before 1st CT scan	5-7	6
Intraoperative CT prep-time before the 1st scan	2-4	3
1st CT scan	1-2	1.5
Prep-time before resuming surgery	3-4	3.5
Total time to insert all pedicle screws	25-69	47
Mean insertion time per screw	6-9	7.5
Surgical prep-time before 2nd CT scan	2-4	3
Intraoperative CT prep-time before the 2nd scan	1-3	2
2nd CT scan	1-2	1.5
Total time for this extra step	45-111	78

Table 10: The Percentage of Number of screws causing Pedicle perforation graded according to the Gertzbein grading.

Gertzbein grading	Number of screws	Percentage
G A	105	80.76%
G B	21	16.15%
G C	4	3.07%
G D & E	0	0

Table 11: Percentage of Surgical Complications.

Complications	Number of Patients	Percentage
Unintended Durotomy	1	5
Screw Malposition	3	15
Infection	1	5

Table 12: Percentage of Clinical Outcomes according to Oswestry Disability Index (ODI) comparing pre and post-operative results.

ODI	Number of Patients				
	Minimal disability (0-20)	Moderate disability (21-40)	Severe disability (41-60)	Cripple (61-80)	Bed bound (81-100)
Preoperative	0	6 (30%)	8 (40%)	6 (30%)	0
Postoperative	13 (65%)	5 (30%)	1(5%)	0	0

Discussion

The biomechanical relevance of improperly positioned pedicle screws has also been shown in numerous investigations [19, 20]. It has been demonstrated that pull-out strength is decreased by 8% and 21%, respectively, by breaches in the medial and lateral pedicle cortex [20]. The portion inside the pedicle is thought to be the primary source of a pedicle screw's fixing strength. An extra 20% of strength is added by purchase in the anterior vertebral body cortex and the cancellous bone of the vertebral body [19, 21-22]. Additionally, the necessity for image-guided screw placements to increase accuracy has been further underlined by medicolegal concerns about patient safety.

Although the amount of reported screw misplacement is often minor, it does not account for the possible influence on patient morbidity. More alarming statistics regarding screw misplacement are shown by per-patient analysis. The number of patients with misplaced pedicle screws will probably rise in direct proportion to the increased use of these devices. Better techniques for assessing screw placement were therefore developed [23].

Several techniques have been developed to decrease morbidity related to screw malposition and increase the accuracy of pedicle screw placement. Accurate pedicle screw placement and higher procedural success rates have been made possible by the incorporation of imaging and image guided surgery (IGS) technologies into spine fusion [24, 25].

The scope of image-guided surgery has expanded due to technological advancements. A systematic analysis of 26 prospective studies on the precision of 6617 thoracolumbar pedicle screw placement using different procedures was conducted by Gelalis *et al.* [26]. According to their findings, while utilizing the freehand approach, 69-84 percent of the screws were totally contained in the pedicle; when using fluoroscopy, 68-85 percent; when using fluoroscopy-based navigation, 81-92 percent; and when using CT navigation, 89-100 percent. As a result, robot-guided surgery or CT navigation could be the most dependable method for achieving precise pedicle screw insertion.

The present study aimed at evaluating the operative details of using intraoperative CT (Airo) with navigation in dorso-lumbo-sacral fixation surgeries. Twenty patients suffering from a spinal instability were encrypted with their data in this study.

In our study males constituted 80% of the patients of the study while females constituted 20% of them with a male to female ratio equal to 4:1. This higher male incidence especially in fracture dorsolumber spine correlate with the findings of Ketan Khurjekar *et al.* [27] where male to female ratio was 8:1. Also correlate with another study concerned about degenerative lumbar spondylolisthesis prevalence, where male to female ratio was 1.3:1 in elderly patients [28].

For lumbar canal stenosis it was also found by Timothy *et al.* that incidence is higher in males than females especially in age group (40-49y) it was 1.7 in females and 2.2 in males [29]. The mean age of the patients in our study was 24.3 year with the age ranging from 20 to 60 years which is nearly corresponded to Ketan Khurjekar et, al. [27] who reported a mean age of 33 years in fracture spine in males ranging from 18 to 59 years. But in another study done by Ching-Yu Lee, *et al* [30] the average age was 60.1 years; ranging from 23–75 years.

In our study 45% of cases indicated for stabilization were degenerative spondylolisthesis and this correlate with the study of Anantha Gabbita *et al* [31] where degenerative cases represent 72% of their study. In our study 35% of the cases were fracture spine and all of these cases involve the transitional area (T11-L2) this correlate with the study of Hamed Ahmed Alnefaie *et al* [32] where transitional area fracture represent 50%-60% of their study and 25%-40% of these cases impacted the lower thoracic spine. Also, this correlate with the study of Ketan Khurjekar *et al* where fracture of (D12-L1) represent 60% of his study [27]. We had one case of Upper thoracic spinal TB with vertebral collapse, progressive kyphosis and neurologic neurologic deficit which indicated it to under-go fixation.

In our study also all degenerative spondylolisthesis was L4-5 and L5-S1, this correlate with the study of Yasuchika Aoki *et al* [33] where these 2 levels represent 97.2% of all cases with spondylolisthesis. In our study in lumber canal stenosis L4-5 was the most affected level and this correlate with the study of lee Sy *et al*, [34] where L4-5 level is involved most frequently.

Posterior surgery with long segment instrumentation was performed in our study for all patients with fracture spine as the immobilization of at least 2 vertebrae above and 2 below the fracture to prevent kyphosis, this correlate with the study done by M. Vassal *et al*, [35] who also recommended long segment instrumentation in cases where kyphosis angulation was important. In degenerative spondylolisthesis we did stabilization plus decompression, to prevent secondary destabilization, and this give best results, this correlate with the study of P. Guigui *et al*, [36] in which they found that instrumentation is the reference attitude, showing good long-term results. For cases with multilevel canal stenosis we did posterior decompression, with posterior instrumented fusion and this correlate with the study of Zouboulis E Panagiotis *et al*. As they found that decompression with fixation offers promising and reproducible clinical and radiographic results in patients suffering from multilevel lumbar spinal stenosis [37].

For thoracic spine we used screw with diameter range from 4.5-6.5 mm, length range from 25-40 mm and this correlate with the study of E.N. Muteti *et al* [38] who recommended using these dimensions for lower thoracic pedicular screws. For lumber spine (L1-4) we used screw with diameter mean 6 mm and length (40-45 mm) but for lumber 5 we used same diameter but length (45-50 mm). For S1 the diameter was 4.5-5 mm and the length was (35-40 mm). This dimension was aided by the guidance of AIRO and it correlates with the one used by Bernard *et al* [39] who suggested the same dimension for Transpedicular screw insertion. Compared to non-navigated spinal instrumentation, there were some additional steps, the average time for this was calculated and it ranges between 20 to 42 minutes, this correlate with the study of Nils Hecht *et al*, in which these extra steps took from 30 to 50 minutes [40].

Like any new technology, intra-operative CT with navigation has a learning curve. We found that as the learning curve increased, the additional stages following the first four operations required less time, indicating that our experience with it was quite effective. Approximately five cases may be required for surgeons with image-guidance skills to have adequate expertise with this technology, according to several research examining the learning curve related with intraoperative CT image guidance usage [41]. Thus far, guided spinal instrumentation has proven to be advantageous in our department's training of young spine surgeons, despite initial worries that its habitual usage could have a negative impact.

Using anatomical landmarks as a guide, we first locate the screw entry points during surgery. This allows us to confirm the entrance position immediately with the help of imaging guidance. Additionally, we observed that even with obese patients, the quality of the images was excellent. For example, we only required two CT scans for each surgery-one at the beginning and one after the screws were inserted-so it didn't take much time to check the accuracy of the screws. These high-quality images allowed us to check every screw in three dimensions and allowed for direct navigation revision when necessary, which helped to avoid revision surgery. Additionally, the high scan resolution and detail quality produced very little hardware artifacts, which is a crucial safety feature as it allows for more precise intraoperative screw assessment.

So, we might say that with usage of intraoperative CT with navigation we consume more time with these extra steps but this prevents severe screw malplacement which need revision surgery. Additionally, because lead-shielded vests are no longer necessary and the surgical team is exposed to less radiation, it improves the safety and comfort of the operating personnel [42, 43].

Using the axial, coronal, and sagittal reconstruction views of the CT images, we evaluated the screw accuracy in our study in accordance with the Gertzbein and Robbins A to E classification criteria [37]. The following levels were part of the grading system: In Grade A, the screw is entirely contained within the pedicle; in Grade B, the screw slightly breaches the cortex of the pedicle; in Grade C, the breach is less than 4 mm; in Grade D, the breach is less than 6 mm; and in Grade E, the breach is more than 6 mm. Screws with an A grade were "perfect," a B grade was "clinically acceptable," and a C–E grade deviated significantly from the intended trajectory and was deemed incorrect.

We had 105 (80.76%) perfect screws and 21(16.15%) clinically acceptable screws so total for accurate screw was (96.91%). On the other side we had 4 (3.07%) screws grade C and all of them were revised intraoperative. We did not have any screw with major breach >4 mm.

This is consistent with a study by Wang *et al.* [43], which found that even with the gross segmental instability and disoriented anatomy brought on by shifting the patient's position, transpedicular screws were placed with 96.4 percent accuracy when treating unstable thoraco-lumber spinal fractures using CT-based navigation. Additionally, Merloz P. *et al.* [44] discovered that the accuracy rate for computer-assisted surgery is 92%. This is also consistent with a study by Lee CY *et al.* [45], which discovered that stabilizing unstable TL spine fractures with transpedicular screw fixation and the intraoperative CT navigation system produced 98 percent accuracy. Furthermore, incorrectly positioned screws could be instantly adjusted using real-time picture confirmation; a follow-up procedure was not necessary to rectify incorrectly positioned screws.

Additionally, this aligns with the research conducted by Hecht N *et al.* [40], who fervently advocate for AIRO as a simple, safe, effective method of spine navigation that produces positive therapeutic outcomes for patients. This study's accuracy rate was 95.7 percent, and there was a possibility of an instant intraoperative correction. In addition to being beneficial to a teaching setting, post-instrumentation intraoperative CT may also be useful in determining the extent of decompression or debulking in cases of complex trauma or tumors.

The first publication on the precision of pedicle screw placement using a new CT-based navigation system was made by Schwarzenbach *et al*. [46]. Using intra-operative CT with navigation, they discovered that 162 lumbar pedicle screws implanted *in Vivo* had a pedicle breach rate of 2.7%. The authors of this study also discussed the surgeons' learning curve, pointing up more inconsistencies in the earlier applications of the technique. In a comparable study, Amiot *et al.* [47] found that of the 294 screws put using intraoperative CT, the rate of misplacement was only 5.4%; no patient needed reoperation, and none had neurological impairments following surgery. The authors came to the conclusion that pedicle screw instrumentation might be made more accurate and safe by using intra-operative CT. The authors concluded that 3-D navigation-assisted screw instrumentation was more precise and time-efficient than traditional methods after discovering a significantly lower rate of operating time in the navigation cohort. Because navigation allows us to track every instrument in the three-dimensional plane, we saw that the overall incidence of complications associated with screw insertion was lower. [40].

With pedicle screw equipment that uses intraoperative CT navigation and increased instrumentation accuracy and precision, there are fewer problems and better results. The Oswestry Disability score, radiologic findings, neurological condition, and other variables are among the many metrics and criteria that are used to forecast surgical success. One of the most important variables for a functional outcome is the ODI score. Our patient's improvement in our study ranged from 30 to 40 percent from their baseline.

Outside of pedicle screw instrumentation, there are numerous other factors that affect the outcome of a spinal fusion treatment. Based on historical data, the reported rate of pedicle screw misplacement can reach up to 20-40%. Nevertheless, only a small percentage of patients have neurological, visceral, or vascular complications-even in studies with such high rates of misplaced screws.

According to a research by Wiesner *et al.* [48], there were 27 cases of screw malposition out of 408 lumbosacral pedicle screws that were put percutaneously. Of the 27 screws that were misplaced, just one was discovered to have resulted in a neurological issue. This may not come as a surprise because, in contrast to neural structures at the cord level, where error margins are smaller, the neural elements of the lumbosacral spine have greater mobility. Therefore, the cervical and thoracic spine may benefit more from the greater accuracy of pedicle screw placement.

The smaller pedicle size and more intricate 3D anatomy of the thoracic spine make screw placement more difficult. Between 16 and 54 percent of the cortical margins of the pedicle are punctured by thoracic screws [49, 50], which increases the risk of bleeding, injury to the nerve roots, and damage to the spinal cord. The aorta and the pleural cavity are two nearby structures that are put in danger by long pedicle screws. This was confirmed by Allam *et al.* [51], who discovered that patients undergoing thoracic spine stabilization can safely be placed with pedicle screws thanks to the great accuracy of the 3D-based navigation technology. It enables the quick identification of screw misplacement, preventing the need for reoperation due to malposition. The 3D-based navigation technique for transpedicular screw placement in the thoracic spine is superior to the free hand technique when compared to the lumbar spine.

In order to prevent nerve element irritation and improve the pull-out strength of the screws, we can therefore conclude that navigation-guided techniques reduce the breach rate of transpedicular screw placement, but they cannot completely eliminate the possibility of mal-positioning. They can, however, correct any mal-positioned screw that violates the cortex by more than 2 mm [52, 53]. The intraoperative correction rate in this study was 3.07 percent, and no additional surgery was needed for revision.

Three key factors-mobilization of the reference frame, spine motion between the frame and the instrumented vertebrae, and related technological issues-contributed to lower navigation accuracy causing TPS misplacement under intra-operative CT navigation. A reference array is secured on the spinous process by clamping the cortical bone to prevent movement of the reference frame; it is not permitted to apply traction to the reference frame using a suction tube or wires for cauterization [54].

Because retracting the wound and dissecting soft tissue will cause the spinal anatomy to migrate, the surgical field should be fully exposed before the CT registration scan. This is done with a self-retaining skin retractor for fixation. Before inserting a pedicle screw, all of the instrumented vertebrae's transpedicular track tunnels should be prepared by drilling under intra-operative CT navigation. This is because spine motion may happen and navigational accuracy will be at its peak right after CT registration.

The operating room needs to change along with intraoperative CT with navigation platforms to make place for new machinery. Even though the previously mentioned devices are all movable, a basic fluoroscopy machine still requires less physical space than the stereotactic tracking camera, CT scanner, and image registration hub. It makes sense that the size and design of the room should be the first important feature that doctors search for in a cutting-edge operating suite.

Another factor to consider is the OR table itself. However, with certain navigation systems, like the Airo, the surgeon, surgical tech, tracking camera, and scanner can all be ideally positioned on a specialized OR table that rotates 360 degrees. This feature is appealing because it makes it simple to adjust the patient's position after scanning, avoiding the need to remove the scanner in the unlikely event that an intraoperative rescan and registration are required due to an unintentional movement of the reference point. Navigation therefore aims to maximize the surgical intervention by giving the surgeon enhanced sight of the operating region and the ability to view the precise location of the handheld device with respect to the bony architecture [55].

Crucially, a complete understanding of spinal anatomy is necessary, and spinal navigation should never be used in place of it. Consequently, in order to identify potential problems and constraints with guided equipment and to handle the scenario in which navigation is not available, residents and spinal surgeons must also be skilled in the use of fluoroscopic and free-hand screw insertion procedures.

The benefits of intraoperative CT with navigation in pedicle instrumentation are evident, and the technology's usefulness appears to be unquestionable. However, because they are more expensive, they don't really improve upon traditional instrumentation methods. The cost-effectiveness of guided instrumentation is thus called into question. Extending the apps on these platforms is one method to mitigate their expense. Subsequent research endeavors examining augmented applications of the technology, like tumor excision and osteotomies in deformity surgery, could furnish the physician with the required tools to justify the equipment's expense.

Conclusion

Intraoperative CT with navigation reduces screw malplacement and if there is intraoperative malplacement this could be corrected immediately and consequently prohibit the need of correction surgery. CT with navigation facilitate fixation surgery in obese patients due to good quality of images also it reduces breach rate. CT with navigation facilitate fixation in thoracic spine as the pedicle is small with complex 3D anatomy. It gives information about adequate cord, thecal sac and nerve roots decompression during surgery. So intraoperative CT with navigation provide easier surgery, greater accuracy, less complications and consequently improves outcome. It declines radiation exposure to surgical team. On the other hand, still cost, wide operating theatre, well trained team and intraoperative technical errors represent challenges.

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