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Minimally invasive cervical spine surgery with navigated guidance

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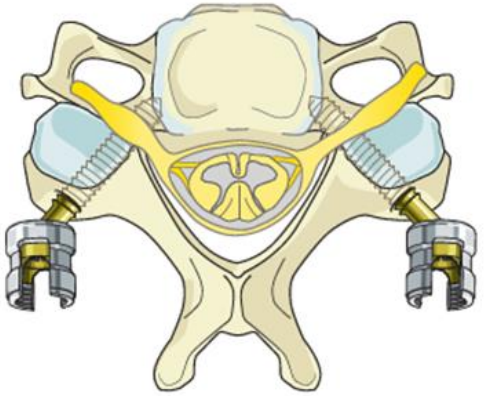
Conflict of interests

- Brainlab: Presentations, consulting

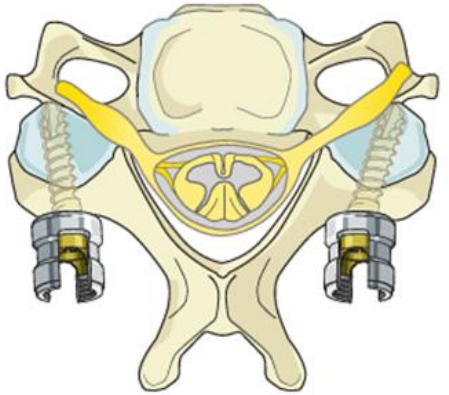
Evolution cervical spine fixation

- Open approach, lateral mass & pedicle screws (anatomic landmarks, c-arm)
- Open approach, pedicle screws (navigated, surface matching)
- Combined open approach & percutaneous pedicle screws (navigated, intraop CT)
- Percutanous/mini-open pedicle screws (navigated, intraop CT)

Pedicle screws



Lateral mass screws



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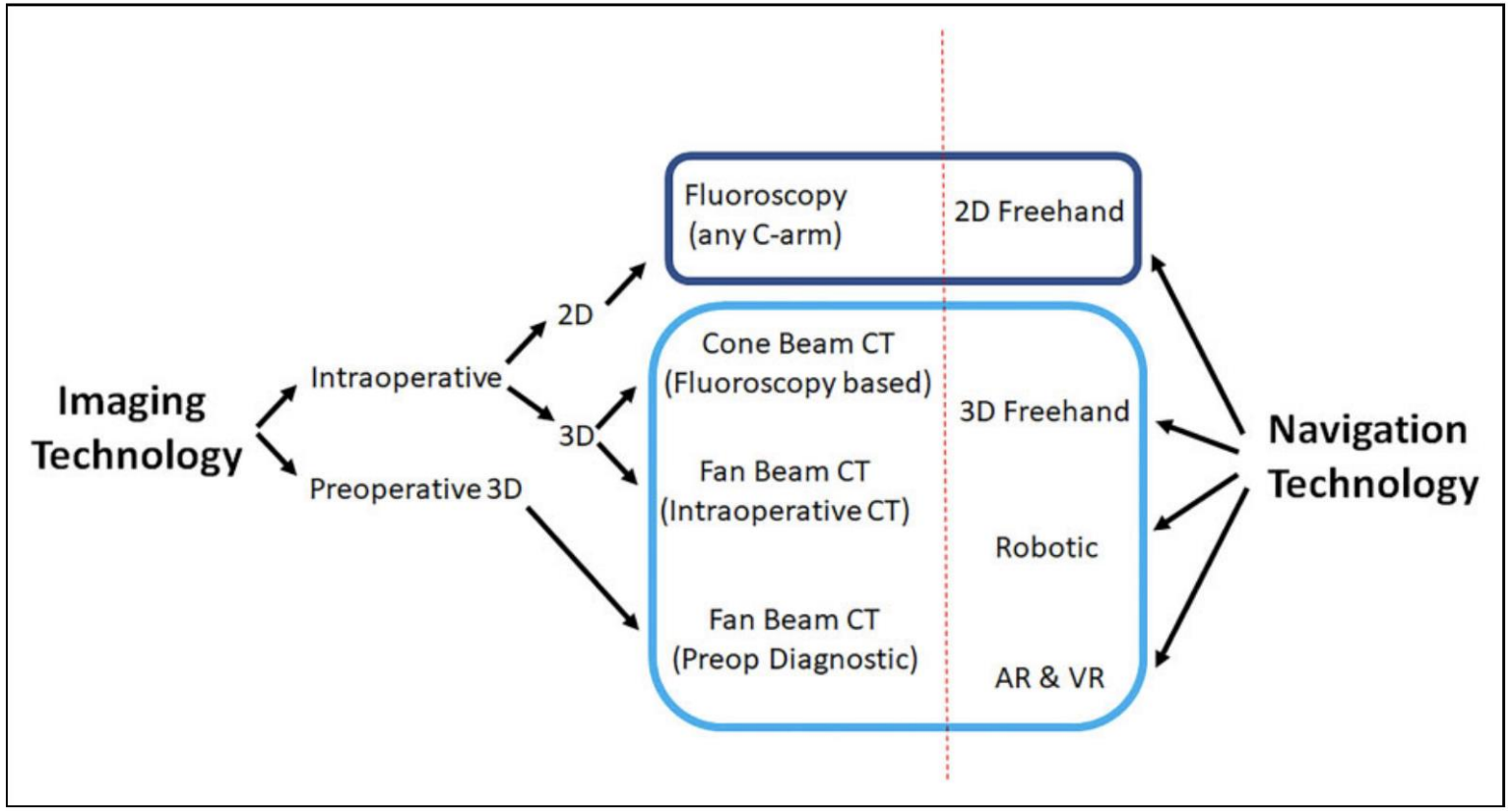
Imaging and navigation



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Cervical pedicle screws are almost 4x stronger

ELSEVIER

The Spine Journal 6 (2006) 667–672

THE SPINE JOURNAL

Cervical pedicle screws vs. lateral mass screws: uniplanar fatigue analysis and residual pullout strengths

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Abstract

BACKGROUND CONTEXT: Although successful clinical use of cervical pedicle screws has been reported, anatomical studies have shown the possibility for serious iatrogenic injury. However, there are only a limited number of reports on the biomechanical properties of these screws which evaluate the potential benefits of their application.

PURPOSE: To investigate if the pull-out strengths after cyclic uniplanar loading of cervical pedicle screws are superior to lateral mass screws.

STUDY DESIGN: An in vitro biomechanical study.

METHODS: Twenty fresh-frozen disarticulated human vertebrae (C3–C7) were randomized to receive both a 3.5 mm cervical pedicle screw and lateral mass screw. The screws were cyclically loaded 200 times in the sagittal plane. The amount of displacement was recorded every 50 cycles. After cyclical loading, the screws were pulled and tensile load to failure was recorded. Bone density was measured in each specimen and maximum screw insertion torque was recorded for each screw.

RESULTS: During loading the two screw types showed similar stability initially, however the lateral mass screws rapidly loosened compared to the pedicle screws. The rate of loosening in the lateral mass screws was widely variable, while the performance of the pedicle screws was very consistent. The pullout strengths were significantly higher for the cervical pedicle screws (1214 N vs. 332 N) and 40% failed by fracture of the pedicle rather than screw pullout. Pedicle screw pullout strengths correlated with both screw insertion torque and specimen bone density.

CONCLUSIONS: Cervical pedicle screws demonstrated a significantly lower rate of loosening at the bone–screw interface, as well as higher strength after fatigue testing. These biomechanical strengths may justify their use in certain limited clinical applications.

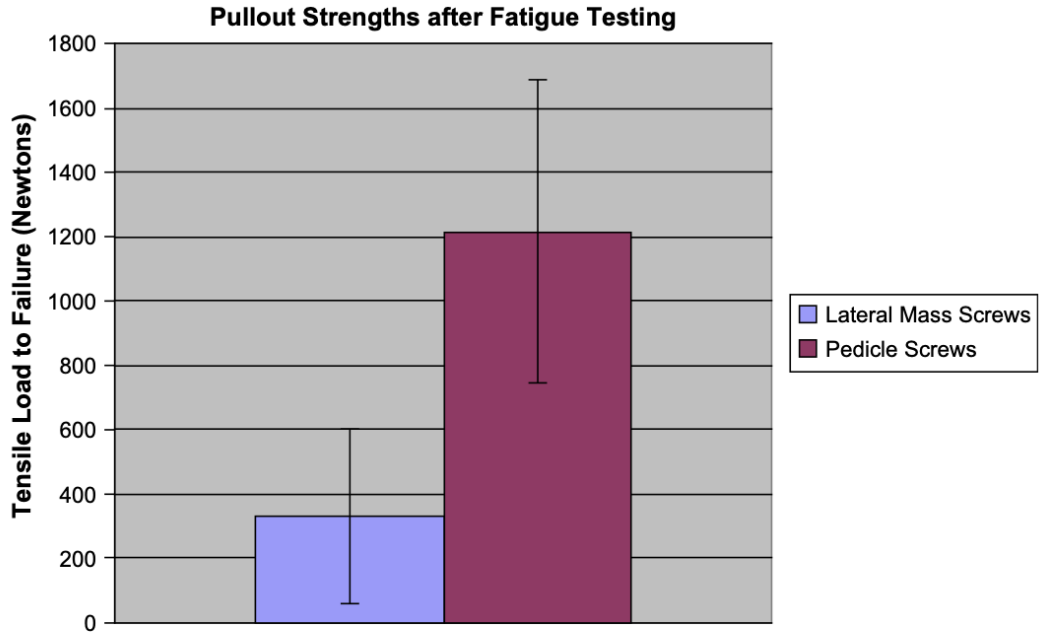

Fig. 5. The mean pedicle screw pullout strength after cyclic loading was almost four times that of the lateral mass screws.

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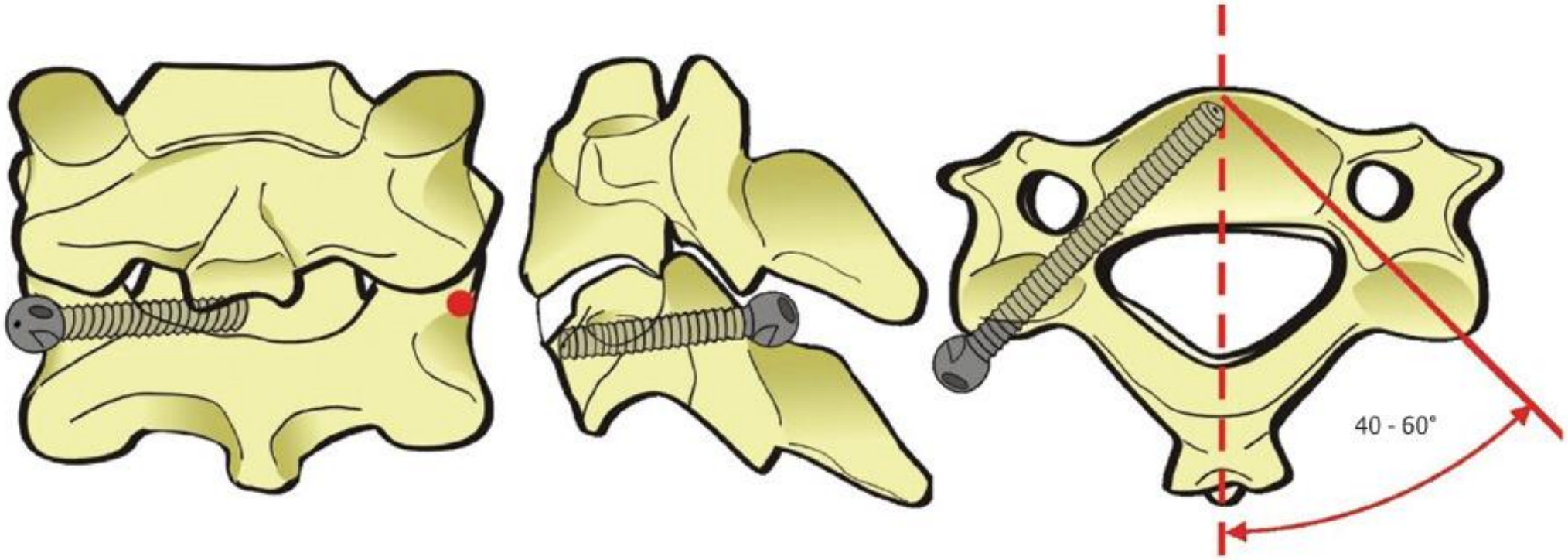
Cervical pedicle screws



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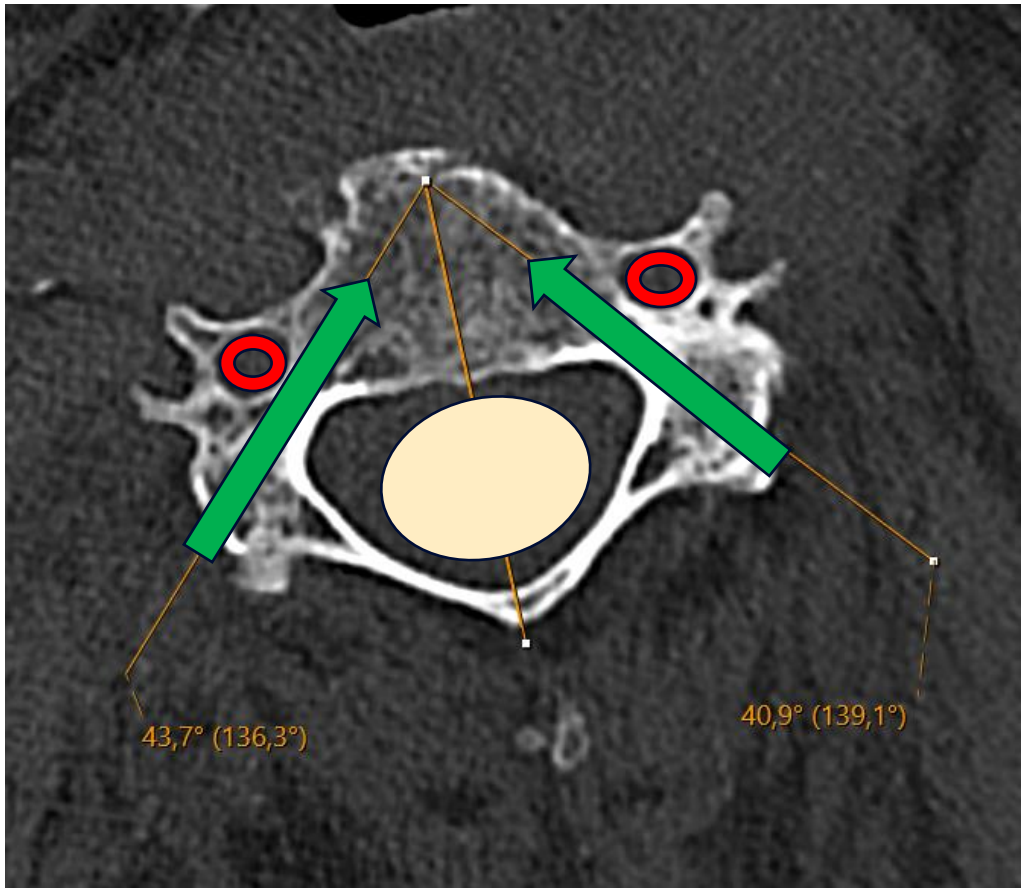
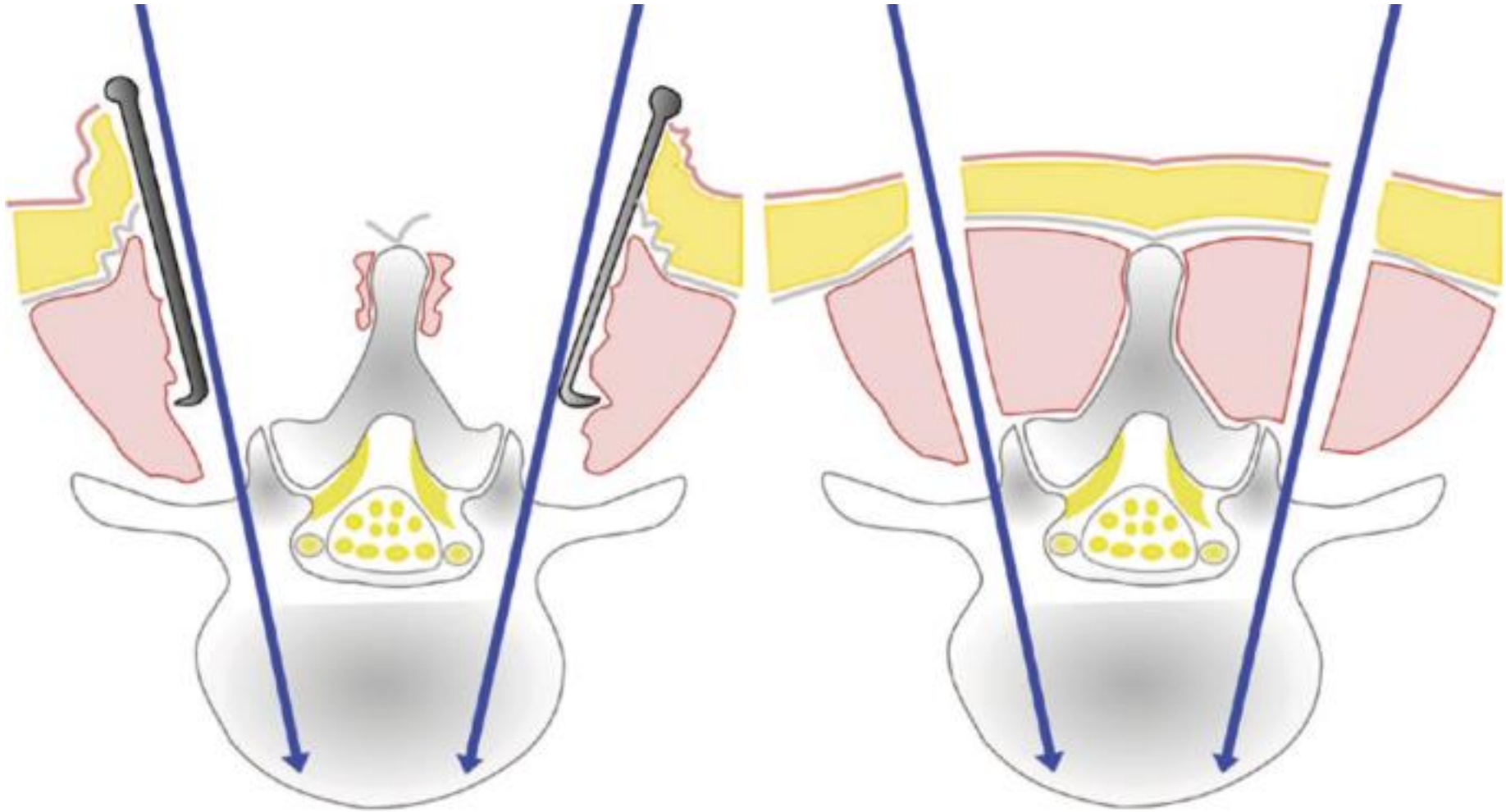
Risks with pedicle trajectories





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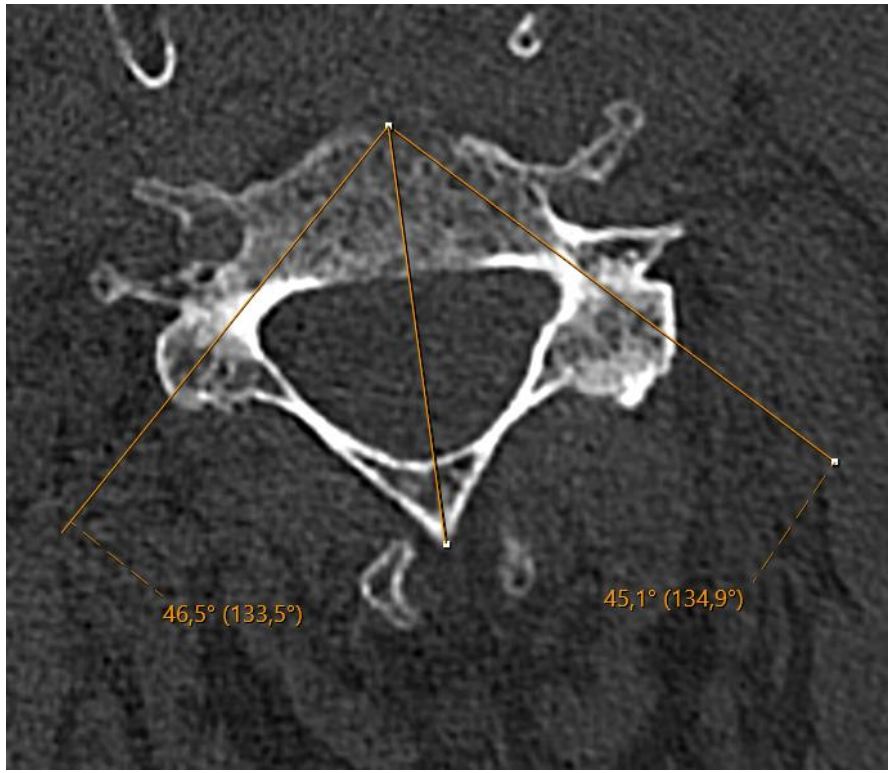
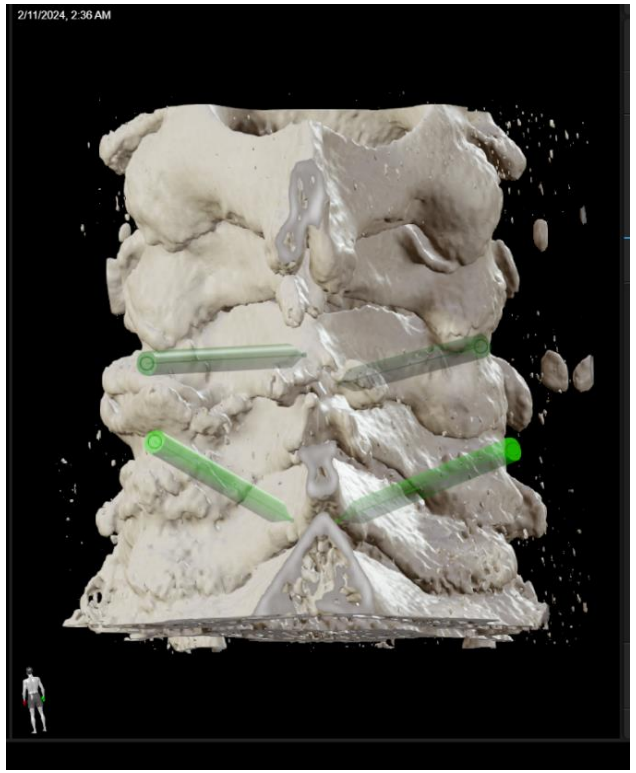
Cervical pedicle screw planning





International Journal of Spine Surgery, Vol. 14, Supplement 3, 2020, pp. S14–S21
https://doi.org/10.14444/7122

Percutaneous, Navigated Minimally Invasive Posterior Cervical Pedicle Screw Fixation

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ABSTRACT

Background: Cervical pedicle screws provide significant biomechanical advantage but can be technically challenging and associated with morbid exposure. Improvements in intraoperative navigation guidance and instrumentation have made feasible this biomechanically robust, but technically challenging procedure. We present our initial experience with minimally invasive (MIS) percutaneous pedicle screw fixation in the cervical atlantoaxial and subaxial spine.

Methods: A retrospective review was performed on 27 cases that involved a novel MIS percutaneous cervical pedicle screw technique. Small lateral skin incisions were made bilaterally on the neck using intraoperative navigation guidance. Subsequently, navigated, percutaneous screws were placed using the Proficient Minimally Invasive System (PROMIS; Spine Wave, Shelton, CT). Computed tomography (CT)–guided navigation was used for cervical pedicle screw placement with subsequent placement of percutaneous rods.

Results: Indications for surgery included type II odontoid fractures, subaxial fracture dislocations and burst fracture, metastatic pathological burst fracture, and degenerative spondylosis with stenosis. There were 15 men and 12 women, with an average age 63.5 years. Follow-up ranged from 3 to 24 months (average = 16.7 months). One screw was revised intraoperatively. Two patients (7.7%) required reoperation, 1 patient required repositioning of a C5 pedicle screw, and 1 suffered a C7 body fracture. No nerve root injury, spinal cord injury, or vertebral artery injuries were reported.

Conclusions: Percutaneous cervical pedicle screw fixation is a feasible and safe technique when performed with CT-guided intraoperative navigation techniques. Cervical pedicle screw fixation provides a biomechanically superior construct in comparison with a lateral mass technique. In addition, the lack of paraspinal muscle disruption preserves important stabilizers of the posterior ligamentous complex and may reduce wound-healing issues in high-risk cases (eg, trauma patients). Although the current role for percutaneous instrumentation is relatively narrow, the advancement of MIS posterior cervical techniques may provide expanded opportunities in the future.

Special Issue

Keywords: cervical pedicle screws, minimally invasive, percutaneous, navigation

Global Spine Journal
Volume 12, Issue 2_suppl, April 2022, Pages 27S-33S

https://doi.org/10.1177/21925682211029215

SAGE journals

Special Issue Article

Percutaneous Posterior Cervical Pedicle Instrumentation (C1 to C7) With Navigation Guidance: Early Series of 27 Cases

Domagoj Coric, MD[1], and Vincent Rossi, MD, MBA[2]

Study Design: This is a technique paper describing minimally invasive, navigated, percutaneous pedicle screw fixation of the cervical spine. In addition, we include a retrospective feasibility analysis of our initial experience with 27 patients undergoing this procedure.

Objective: The purpose of this study is to describe the technique of MIS navigated percutaneous cervical pedicle screw instrumentation and to report our initial experience.

Methods: This is a retrospective review of 27 patients undergoing MIS navigated percutaneous posterior cervical pedicle screw fixation at 2 institutions. We describe the technique and report the radiographic outcomes and all intraoperative and postoperative complications.

Results: A total of 27 patients underwent MIS navigated percutaneous pedicle screw fixation. Indications included odontoid fracture, subaxial fracture dislocations and burst fracture, pathological fracture, and degenerative spondylosis. There were no nerve root or vascular injuries. There were no spinal cord injuries. Two screws required repositioning intraoperatively, and 1 patient required reoperation for symptomatic malpositioned screw.

Conclusions: MIS navigated percutaneous posterior pedicle screw fixation can be performed safely. These constructs are biomechanically superior with neurovascular complication rates comparable to traditional lateral mass screw technique. While the current indications for this technique are relatively limited, the evolution of MIS cervical decompression techniques as well as navigation and robotics will provide an expanded role for percutaneous cervical pedicle screw instrumentation.

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67 patients w/cervical injury

Safe & effective

Minimal injury to the paraspinal muscles

Minimally Invasive Cervical Pedicle Screw Fixation (MICEPS) via a Posterolateral Approach

Takamitsu Tokioka, MD, PhD and Yoshiaki Oda, MD, PhD

Abstract: Cervical pedicle screw (PS) fixation provides great mechanical strength; however, it needs wide soft tissue detachment and has vertebral artery damage risk. Minimally invasive cervical pedicle screw (MICEPS) fixation, a new method for cervical PS fixation through a posterolateral approach, was developed to reduce soft tissue damage and avoid lateral misplacement of screws. Sixty-seven patients with cervical injury underwent MICEPS fixation. They were positioned prone on a radiolucent carbon table with a carbon Mayfield frame. A reference frame was attached to the spinous process through a small skin incision. One or 2 lateral incisions were made for screw insertion under navigation guidance. After the nuchal fascia was cut, the lateral mass was exposed with blunt dissection between the levator scapulae and splenius muscles. A self-retaining tubular retractor with illumination was applied between split muscle fibers. A 1.4-mm K-wire was inserted using an electric driver under navigation guidance. Drill and tap and cannulated PSs were sequentially inserted over the K-wire; facet fusion via bone grafting can be performed at this time. The rod was placed to the screw head. This technique can reduce intraoperative bleeding and screw deviation rate, with neither of the misplaced screws deviating laterally in the MICEPS group.

Key Words: pedicle screw fixation, cervical spine, posterolateral approach, minimally invasive surgery, navigation system

(*Clin Spine Surg* 2019;32:279–284)

Excellent clinical results with cervical pedicle screws (PSs) have been reported for trauma cases. Although cervical PS fixation can be an essential part of reconstruction in spinal disorders, it has the potential risk of injury to the vertebral artery (VA), as previously described.[1] To avoid lateral misplacement of cervical PS, we developed a new method for minimally invasive cervical pedicle screw (MICEPS) fixation through a posterolateral approach. The preliminary result was reported by Komatsubara et al.[1] This paper describes the novel surgical technique and reports the clinical results.

SURGICAL INDICATION

The indications for MICEPS fixation through the posterolateral approach are the same as those for conventional posterior cervical fusion from C2–C6, such as cervical instability because of trauma, metastatic tumor of the cervical spine, infectious spondylitis of the cervical spine, and segmental instability of degenerative cervical spinal disorders.

CONTRAINDICATIONS

The contraindications for MICEPS fixation are congenital anomaly (ie, defects of the cervical pedicles), traumatic VA aneurysm and bilateral vertebral artery injuries (VAI), and difficulty in prone position.

Issues that should be critically discussed with patients include traumatic VAI and reduction of fracture-dislocations. Patients with fracture-dislocations or fractures of the lateral mass of the cervical spine often have concomitant traumatic VAI, which can lead to brainstem or cerebellar infarction by the maneuver of closed reduction. The ideal situation is for the patient to undergo coil embolization of the injured VA, followed by reduction of the dislocation. Insertion of the PS in the embolized side poses no problem; however, close attention must be paid when inserting screws in the dominant VA side.

INSTRUMENTS AND MATERIALS REQUIRED

The following are required when performing MICEPS fixation: radiolucent operating room table and a carbon Mayfield head holder; intraoperative computed tomography scans and a navigation workstation; intraoperative fluoroscopy; high-speed burr, 1.4-mm guidewires, 2.9-mm cannulated drill, and a power tool; a navigated guide tube; and a cannulated PS and rod system.

POSITIONING AND SURGICAL SETUP

The patient is positioned prone on a radiolucent carbon table with a carbon Mayfield frame to minimize

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The authors declare no conflict of interest.
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Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website, www.jspinaldisorders.com.

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Navigation with 3D imaging (cone-beam CT)

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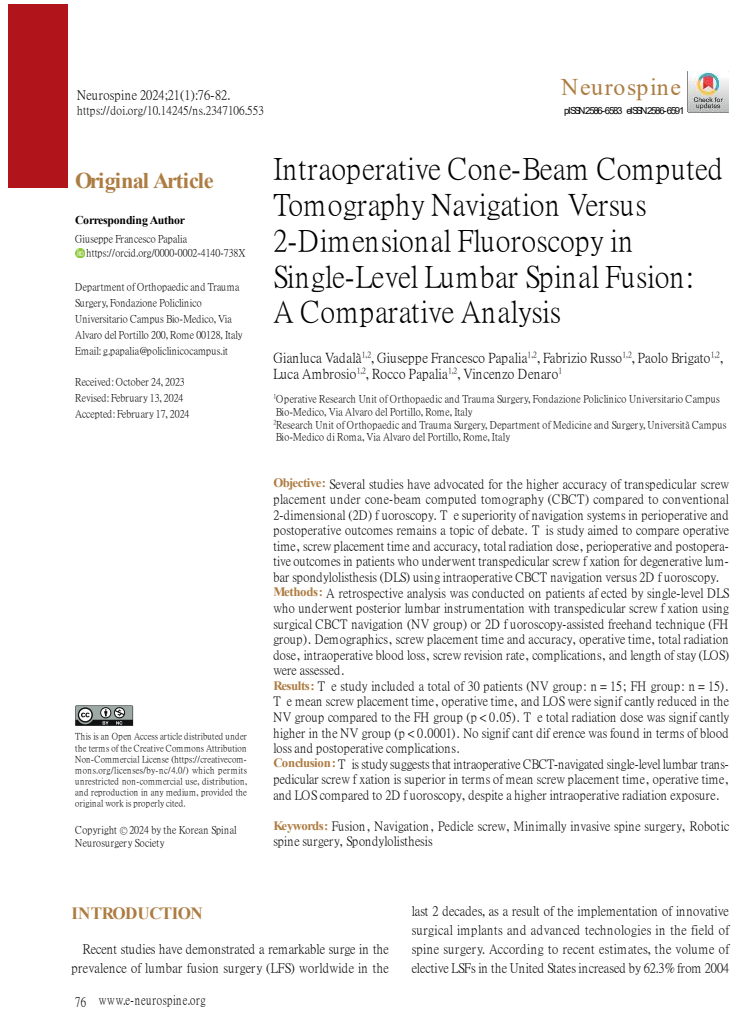
Mobile robotic imaging in spine surgery



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Original Article

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Intraoperative Cone-Beam Computed Tomography Navigation Versus 2-Dimensional Fluoroscopy in Single-Level Lumbar Spinal Fusion: A Comparative Analysis

Gianluca Vadalà[1,2], Giuseppe Francesco Papalia[1,2], Fabrizio Russo[1,2], Paolo Brigato[1,2], Luca Ambrosio[1,2], Rocco Papalia[1,2], Vincenzo Denaro[1]

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[2]Research Unit of Orthopaedic and Trauma Surgery, Department of Medicine and Surgery, Università Campus Bio-Medico di Roma, Via Alvaro del Portillo, Rome, Italy

Objective: Several studies have advocated for the higher accuracy of transpedicular screw placement under cone-beam computed tomography (CBCT) compared to conventional 2-dimensional (2D) fluoroscopy. The superiority of navigation systems in perioperative and postoperative outcomes remains a topic of debate. This study aimed to compare operative time, screw placement time and accuracy, total radiation dose, perioperative and postoperative outcomes in patients who underwent transpedicular screw fixation for degenerative lumbar spondylolisthesis (DLS) using intraoperative CBCT navigation versus 2D fluoroscopy.
Methods: A retrospective analysis was conducted on patients affected by single-level DLS who underwent posterior lumbar instrumentation with transpedicular screw fixation using surgical CBCT navigation (NV group) or 2D fluoroscopy-assisted freehand technique (FH group). Demographics, screw placement time and accuracy, operative time, total radiation dose, intraoperative blood loss, screw revision rate, complications, and length of stay (LOS) were assessed.
Results: The study included a total of 30 patients (NV group: n = 15; FH group: n = 15). The mean screw placement time, operative time, and LOS were significantly reduced in the NV group compared to the FH group ($p < 0.05$). The total radiation dose was significantly higher in the NV group ($p < 0.0001$). No significant difference was found in terms of blood loss and postoperative complications.
Conclusion: This study suggests that intraoperative CBCT-navigated single-level lumbar transpedicular screw fixation is superior in terms of mean screw placement time, operative time, and LOS compared to 2D fluoroscopy, despite a higher intraoperative radiation exposure.

Keywords: Fusion, Navigation, Pedicle screw, Minimally invasive spine surgery, Robotic spine surgery, Spondylolisthesis

INTRODUCTION

Recent studies have demonstrated a remarkable surge in the prevalence of lumbar fusion surgery (LFS) worldwide in the last 2 decades, as a result of the implementation of innovative surgical implants and advanced technologies in the field of spine surgery. According to recent estimates, the volume of elective LSFs in the United States increased by 62.3% from 2004

Vadala et al., Neurospine, 2024

Methods:
30 patients with degen. spondylolisthesis, 15 with CBCT & nav (NV), 15 with free-hand & flouro (FH).

Results:
Mean screw placement time, length of surgery, and length of stay were significantly reduced in the NV group compared to the FH group ($p<0.05$). The total radiation dose was significantly higher in the NV group ($p<0.0001$).

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Mobile robotic imaging in spine surgery

Haida et al. Journal of Orthopaedic Surgery and Research (2024) 19:565
https://doi.org/10.1186/s13018-024-05044-9

Journal of Orthopaedic Surgery and Research

RESEARCH ARTICLE Open Access

Hybrid-3D robotic suite in spine and trauma surgery - experiences in 210 patients

Dominik M. Haida[1,2], Peter Mohr[3], Sae-Yeon Won[4], Thorsten Möhlig[2], Mike Holl[2], Thorsten Enk[5], Marc Hanschen[1] and Stefan Huber-Wagner[1,2*]

Abstract

Background In modern Hybrid ORs, the synergies of navigation and robotics are assumed to contribute to the optimisation of the treatment in trauma, orthopaedic and spine surgery. Despite promising evidence in the area of navigation and robotics, previous publications have not definitively proven the potential benefits. Therefore, the aim of this retrospective study was to evaluate the potential benefit and clinical outcome of patients treated in a fully equipped 3D-Navigation Hybrid OR.

Methods Prospective data was collected (March 2022- March 2024) after implementation of a fully equipped 3D-Navigation Hybrid OR ("Robotic Suite") in the authors level 1 trauma centre. The OR includes a navigation unit, a cone beam CT (CBCT), a robotic arm and mixed reality glasses. Surgeries with different indications of the spine, the pelvis (pelvic ring and acetabulum) and the extremities were performed. Spinal and non-spinal screws were inserted. The collected data was analysed retrospectively. Pedicle screw accuracy was graded according to the Gertzbein and Robbins (GR) classification.

Results A total of $n = 210$ patients (118 m:92f) were treated in our 3D-Navigation Hybrid OR, with 1171 screws inserted. Among these patients, 23 patients (11.0%) arrived at the hospital via the trauma room with an average Injury Severity Score (ISS) of 25.7. There were 1035 (88.4%) spinal screws inserted at an accuracy rate of 98.7% (CI95%: 98.1-99.4%; 911 GR-A & 111 GR-B screws). The number of non-spinal screws were 136 (11.6%) with an accuracy rate of 99.3% (CI95%: 97.8-100.0%; 135 correctly placed screws). This resulted in an overall accuracy rate of 98.8% (CI95%: 98.2-99.4%). The robotic arm was used in 152 cases (72.4%), minimally invasive surgery (MIS) was performed in 139 cases (66.2%) and wound infection occurred in 4 cases (1,9%). Overall, no revisions were needed.

Conclusion By extending the scope of application, this study showed that interventions in a fully equipped 3D-Navigation Hybrid OR can be successfully performed not only on the spine, but also on the pelvis and extremities. In trauma, orthopaedics and spinal surgery, navigation and robotics can be used to perform operations with a high degree of precision, increased safety, reduced radiation exposure for the OR-team and a very low complication rate.

Keywords Robotics, Navigation, Robotic arm, Hybrid OR, Pelvis, Acetabulum, Spine surgery, Trauma surgery, Neurosurgery, Cone beam CT (CBCT)

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Methods:
210 patients operated in 3D-Navigation Hybrid OR (1171 screws)

Results:
1035 (88.4%) spinal screws inserted at an accuracy rate of 98.7%, MIS was performed in 139 cases (66.2%) and wound infection occurred in 4 cases (1,9%). Overall, no revisions were needed.

Haida et al., J Orthop Surg Res, 2024

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MIS cervical pedicle screw placement - Technique

Prone position on carbon table with carbon Mayfield, reference frame on spinous process, 3D-scan (CBCT)

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Mini-open approach in patient with AS

Navigated drill guide, k-wire placement

2 surgeons: navigator-operator concept

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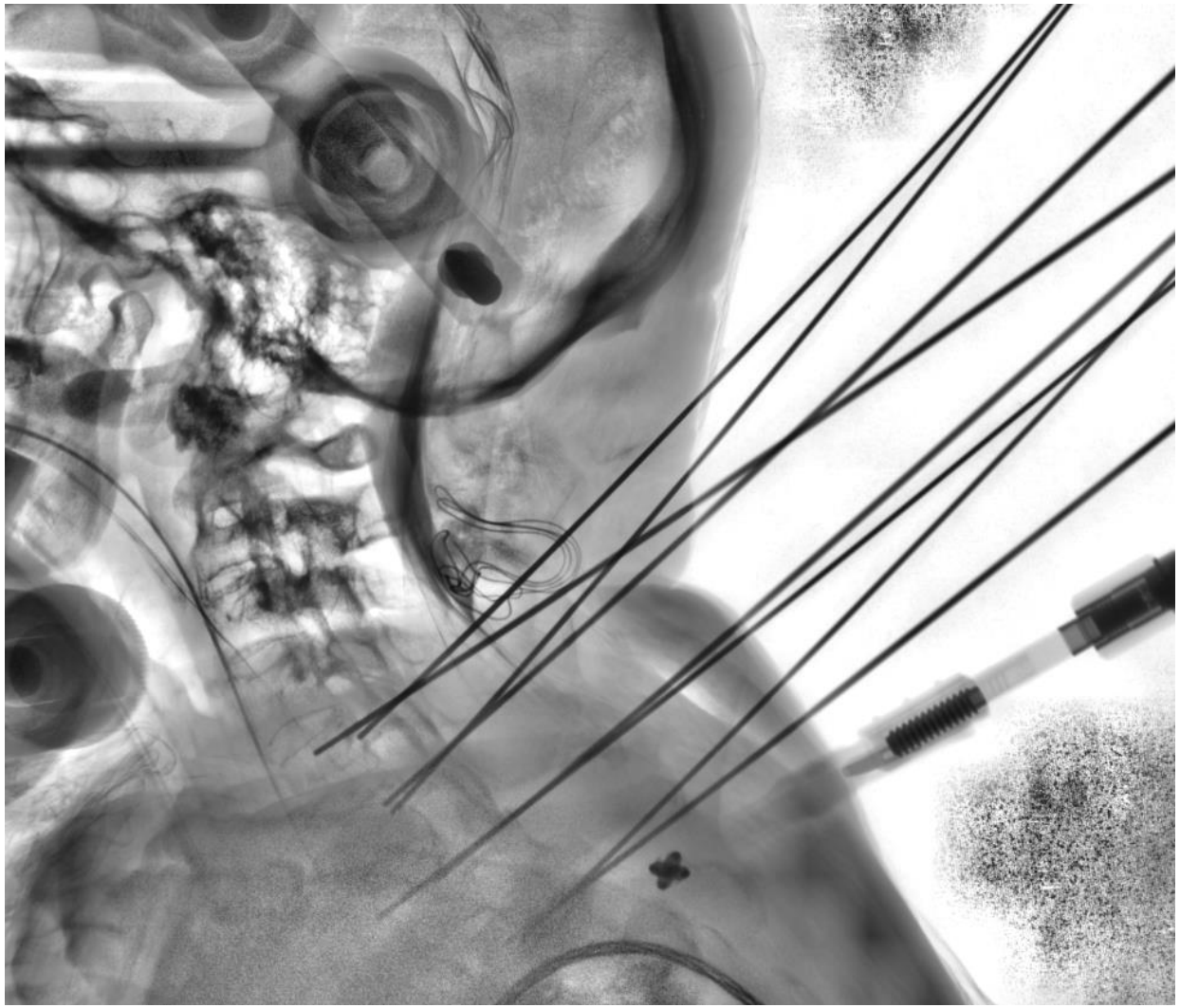

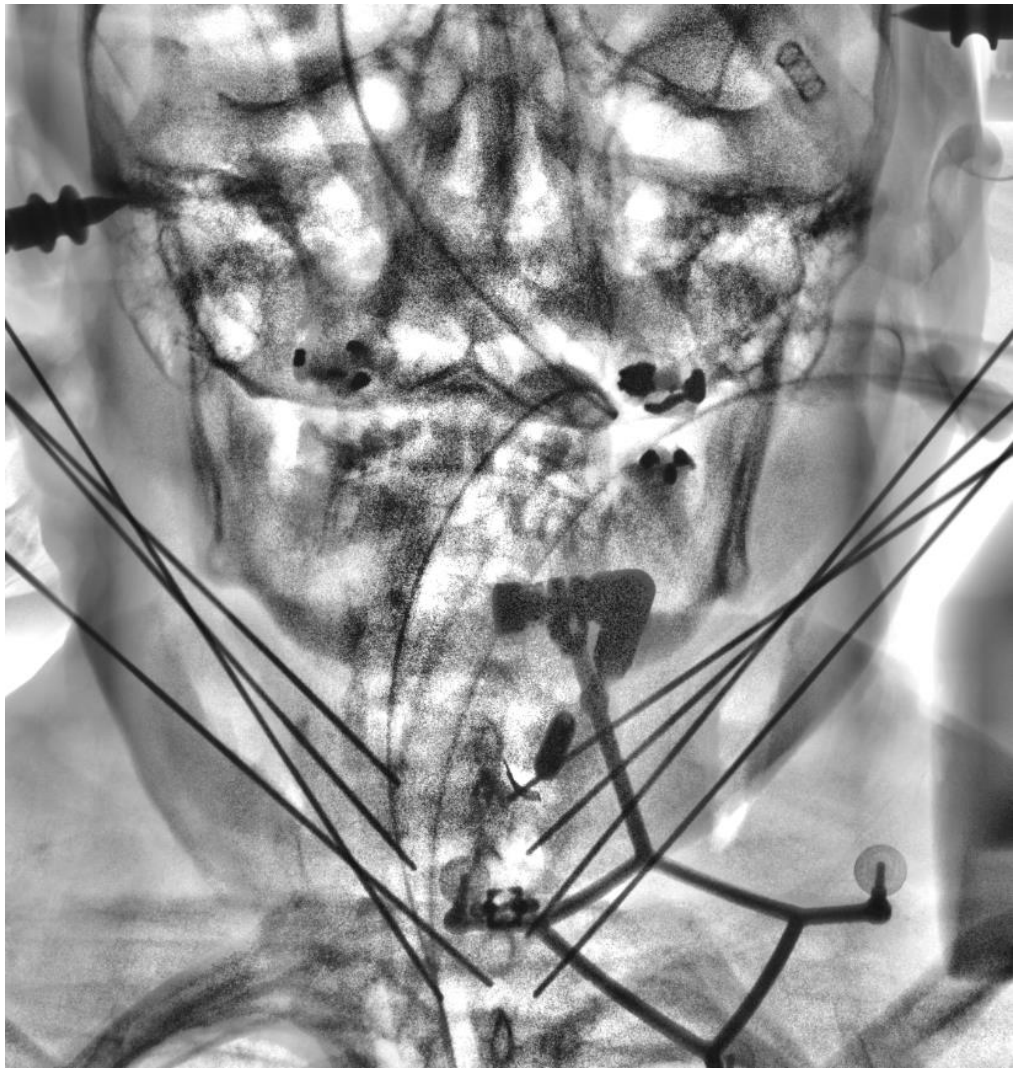

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Navigated tap

Cannulated pedicle screws

Mini-open rod placement

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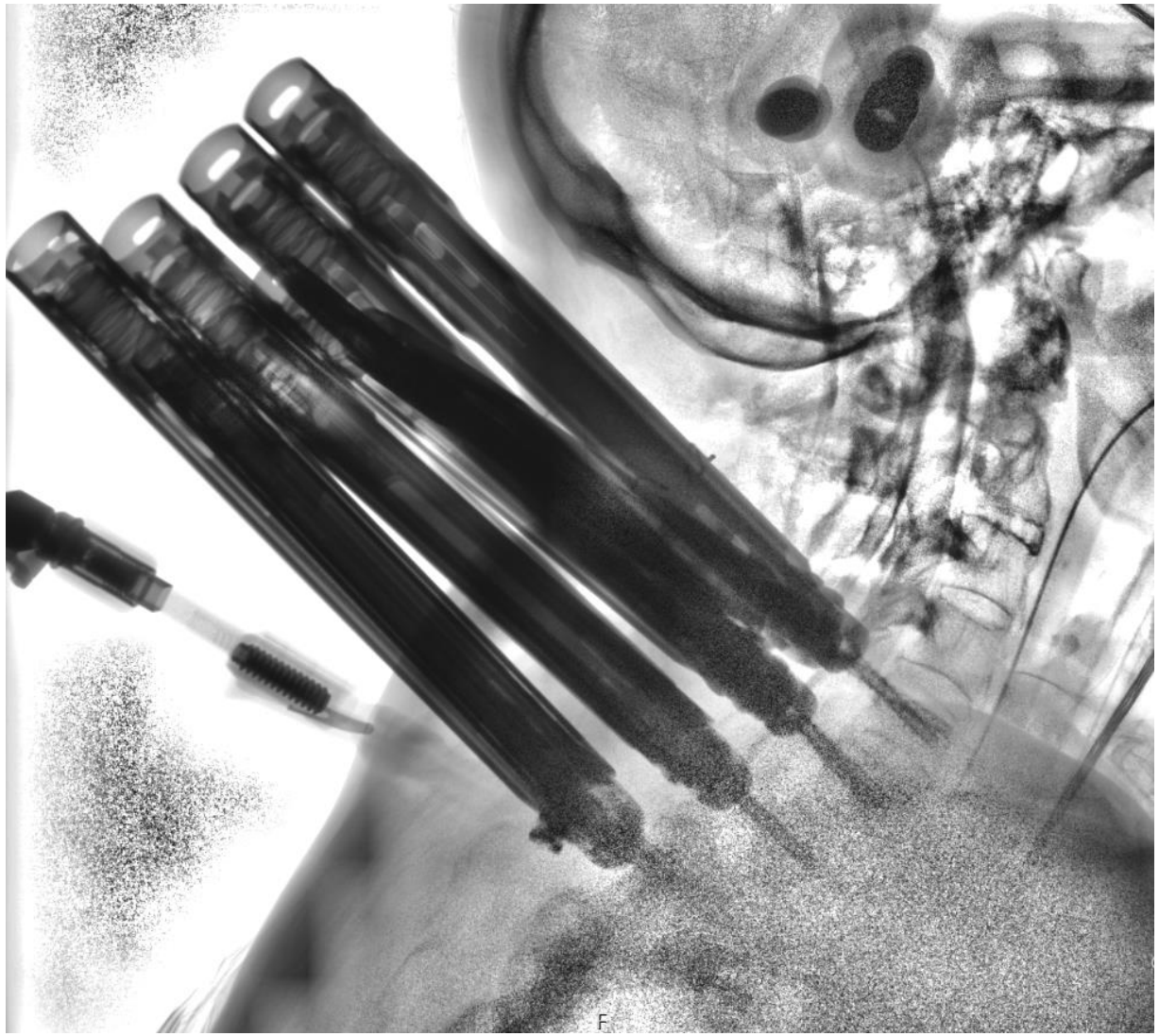

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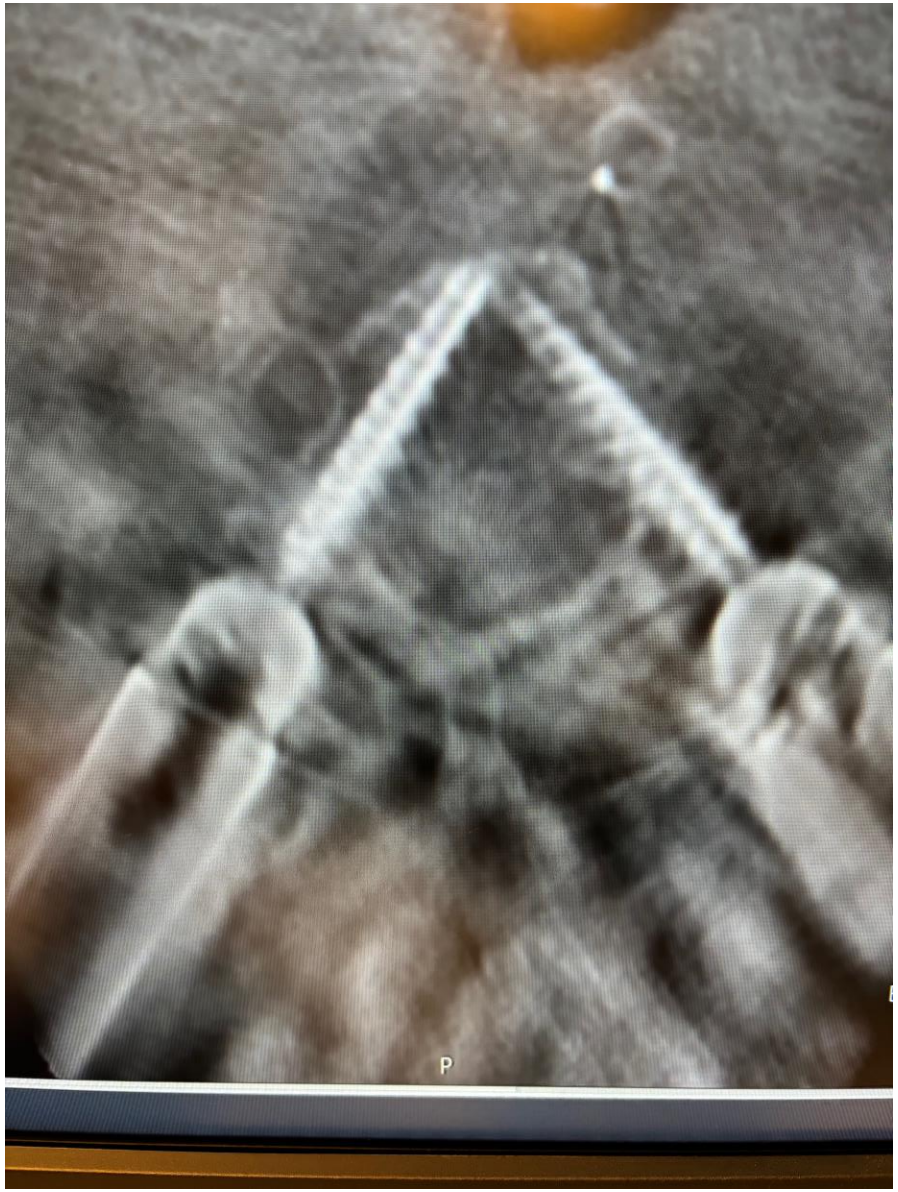
Intraop image controll



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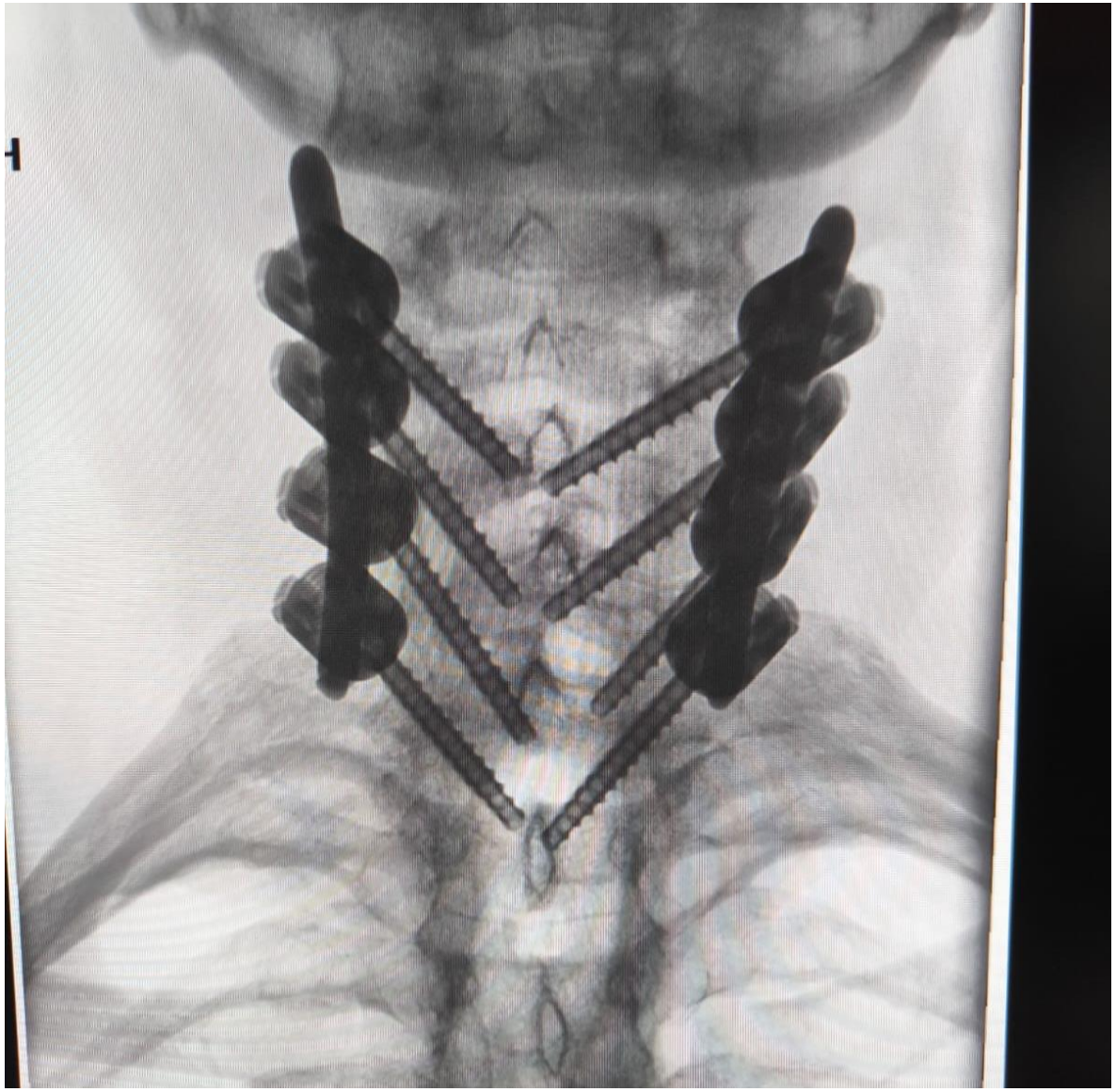
3 months postop



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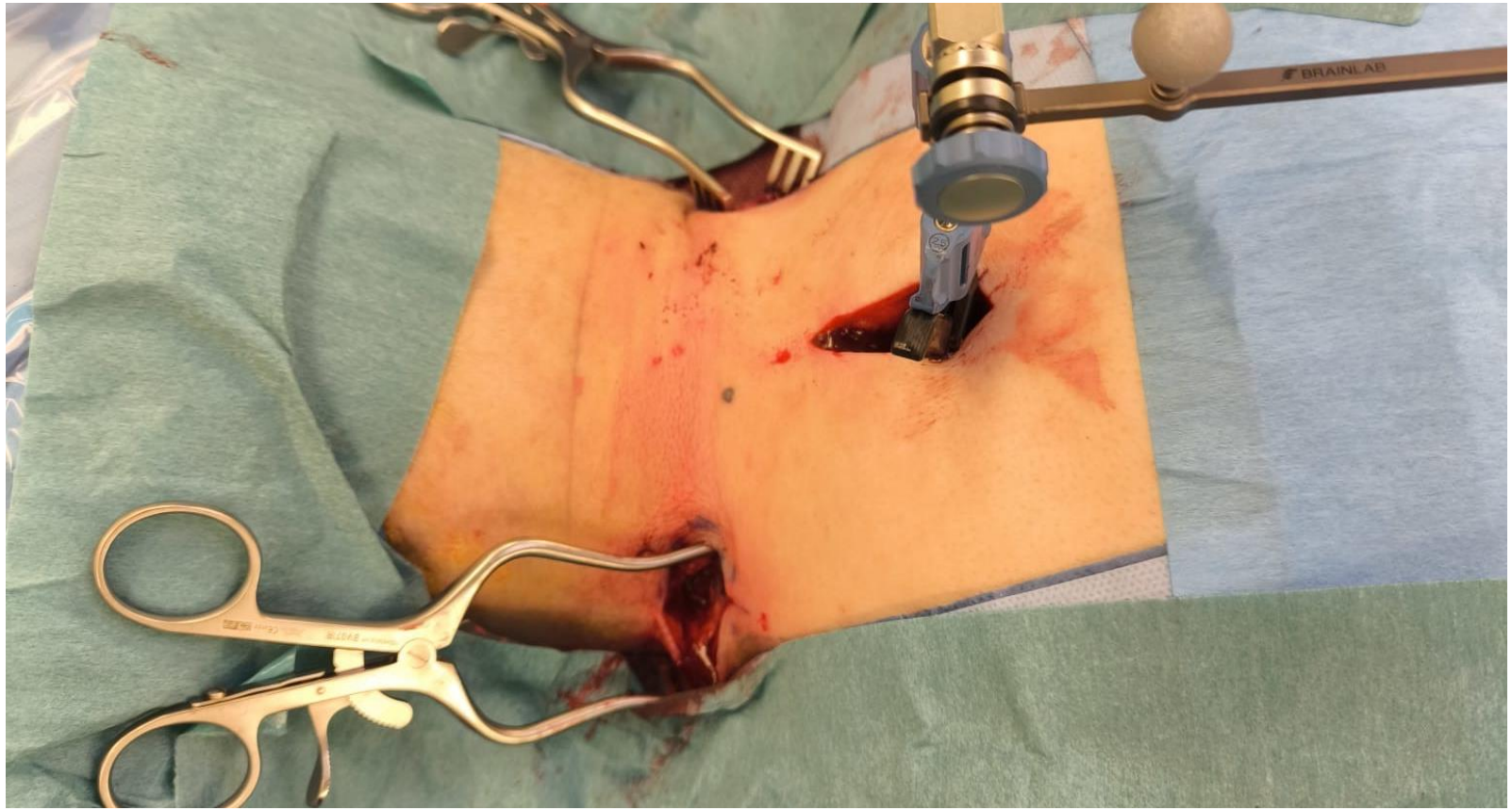
MIS pedicle screw placement

Prone position in Mayfield (carbon), reference frame on spinous process, 3D-scan, navigated incisions and approach



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MIS screw placement

- Navigated drill guide
- K-wire placement

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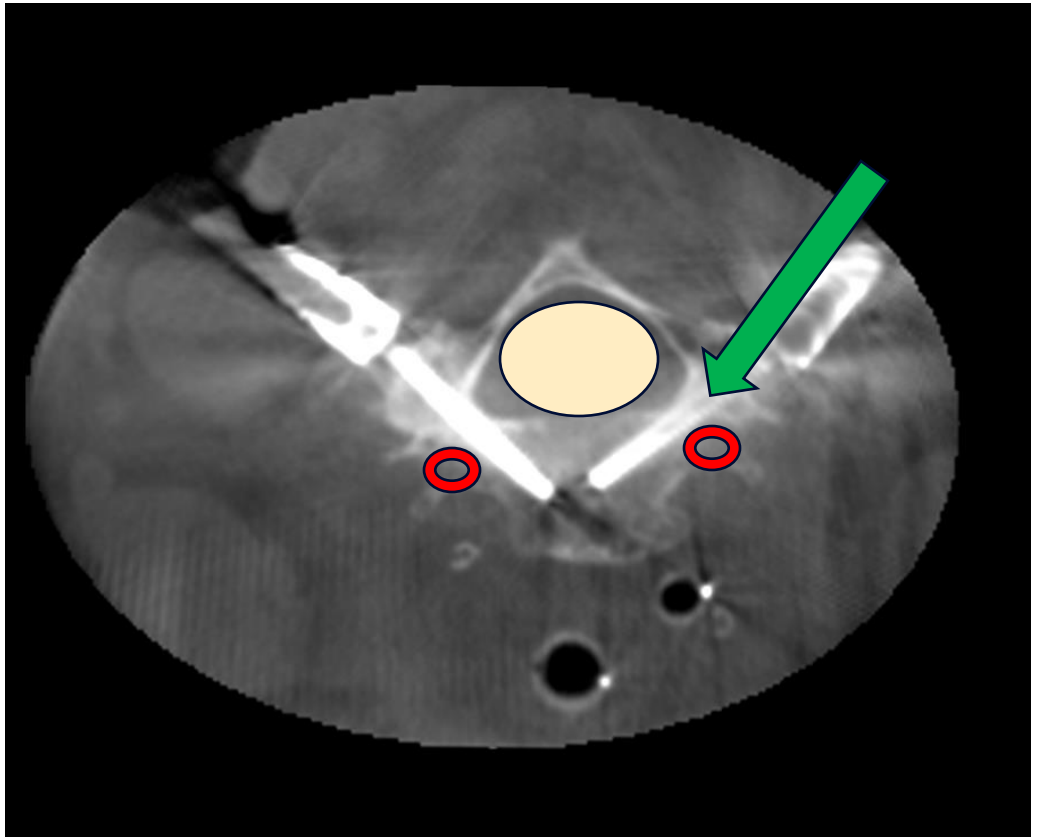
Risk of vascular injury



- Risk of „pushing“ the vertebra with your instrument -> rotation
- Injury to vertebral artery
- Careful drilling with haptic feedback

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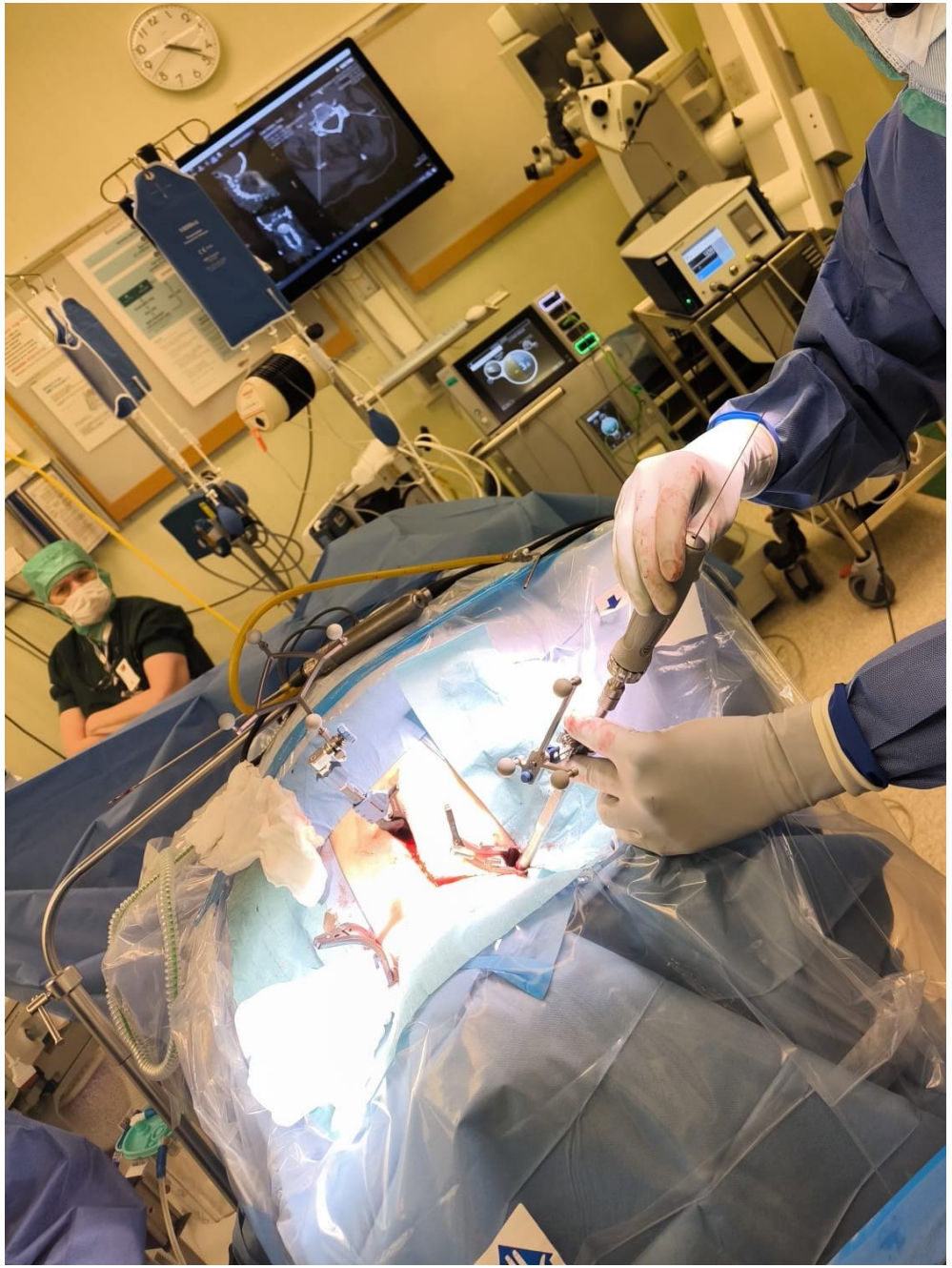
MIS screw placement

- Cannulated pedicle screw placement



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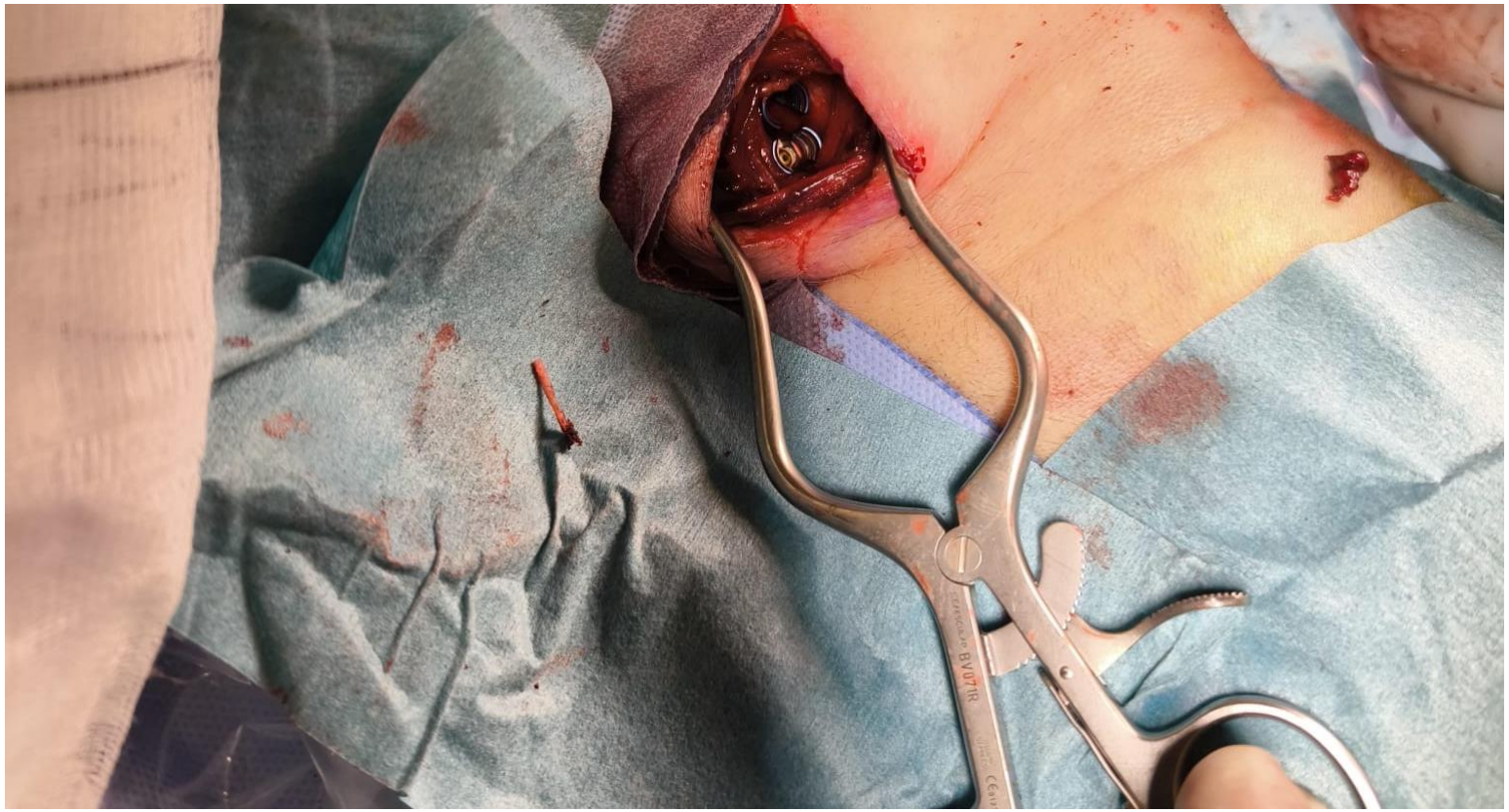
MIS pedicle screw placement - Technique



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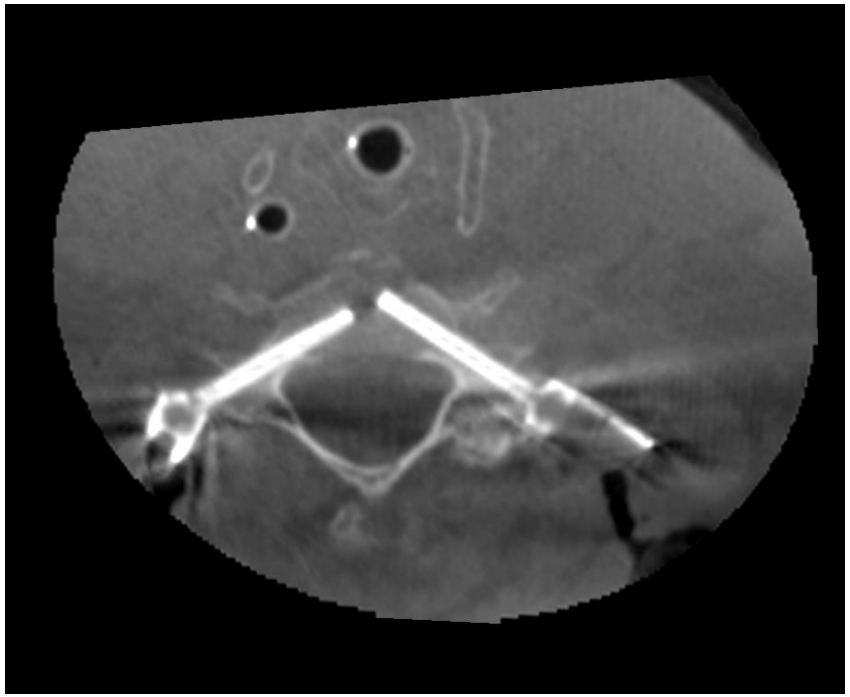
Intraoperative imaging controll of screw placement

Image quality: CBCT (intraop) vs CT (postop)



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Initial experience: Navigated pedicle screw placement

- Comparative pre-post study as part of an internal quality assurance (QA) project

- Patients operated with posterior screw/rod constructs for unstable cervical spine injuries before (pre-group) and after (post-group) introduction of navigated minimal-invasive approach

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Initial experience: Results

Table 1: Characteristics of patients with unstable injuries of the cervical spine operated with open or minimal-invasive approach.

	All patients (n=20)	Open approach (n=10)	MIS approach (n=10)	p-value
Age in years, median (IQR)	65.5 (43.0-73.5)	69.5 (55.0-77.5)	60.0 (38.0-69.5)	0.656
Male sex, n (%)	13 (65)	5 (50)	8 (80)	0.349
BMI, mean (SD)	26.4 (5.0)	27.4 (6.9)	25.4 (2.0)	0.385
Spinal cord injury, n (%)	6 (30)	4 (40)	2 (20)	0.628
ASIA grade, n (%)				
A	1 (5)	0	1 (10)	
B	0	0	0	
C	3 (15)	2 (20)	1 (10)	0.471
D	2 (10)	2 (20)	0	
E	14 (70)	6 (60)	8 (20)	

MIS – minimal-invasive surgery; BMI – body mass index; ASIA – American Spinal Injury Association; IQR – interquartile range; SD – standard deviation

Initial experience: Results

Table 2: Surgical variables of patients with unstable injuries of the cervical spine operated with open or minimal-invasive approach.

	All patients (n=20)	Open approach (n=10)	MIS approach (n=10)	p-value
Use of navigation, n (%)	18 (90)	8 (80)	10 (100)	0.474
Instrumented vertebrae, mean (SD)	3.5 (1.9)	4.5 (2.1)	2.4 (0.8)	*0.008*
Number of screws, mean (SD)	6.8 (3.5)	8.7 (3.8)	4.8 (1.7)	*0.009*
Number of pedicle screws, mean (SD)	4.5 (2.3)	4.1 (2.8)	4.7 (1.7)	0.512
Number of lateral mass screws, mean (SD)	2.2 (2.9)	4.4 (2.7)	0	-
Length of surgery in minutes, mean (SD)	157 (51)	183 (55)	132 (32)	*0.020*
Blood loss in ml, mean (SD)	518 (586)	891 (629)	145 (140)	*0.002*
Length of stay in days, mean (SD)	6.4	6.7	6.2	0.886
Readmission within 30 days, n (%)	2 (10)	2 (20)	0	-
Reoperation within 30 days, n (%)	2 (10)	2 (20)	0	-

MIS – minimal-invasive surgery; SD – standard deviation

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Initial experience: Results

Table 3: Radiological grading of screw placement according to the Bredow classification.

	All patients (n=20)	Open approach (n=10)	MIS approach (n=10)
Number of screws, n (%)	135 (100)	87 (100)	48 (100)
Bredow grade 1	111 (82)	68 (78)	43 (90)
Bredow grade 2	23 (17)	18 (21)	5 (10)
Bredow grade 3	1 (1)	1 (1)	0
Bredow grade 4	0	0	0
Bredow grade 5	0	0	0

MIS – minimal-invasive surgery

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Initial experience

- Stable constructs with fewer screws
- Less invasive than anterior approach (hoarsness, swallowing)?
- Accurate screw placement with navigation and intraoperative CT
- Reduced blodd loss, pain & length of stay
- Feasable alternative
- Cannulated, cervicle pedicle screws with tabs/towers not on the market yet (Norway)

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Thank you for your attention!