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First Experience: The Use of Spine Navigation at Arifin Achmad General Hospital, Riau Province: A Case Report

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Abstract

Background: Neuronavigation is a navigation system that assists neurosurgeons in performing surgery using real-time three-dimensional images from CT, MRI, or C-arm, providing benefits such as shortened operation duration, increased accuracy, and reduced radiation exposure for both patients and operators. In Indonesia, the use of neuronavigation in spine surgery is still rare, and no literature explains the experience of using this technology.

Case Report: We reported the first experience of using neuronavigation at Arifin Achmad General Hospital, Riau Province, in a case of thoracic canal stenosis. A 53-year-old male patient, a palm oil farmer, presented with weakness in both lower limbs, urinary and fecal incontinence, and increased physiological reflexes. MRI examination revealed spinal cord stenosis at thoracic discs VII-X. The patient underwent decompressive laminectomy and posterior stabilization assisted by neuronavigation. The use of neuronavigation allowed precise and efficient placement of surgical instruments, dynamically displayed on the monitor screen, reducing radiation exposure and increasing the accuracy of pedicle screw placement.

Conclusion: The use of navigation technology in spinal surgery will be an innovation that increases efficacy and patient safety. Its adoption is expected to become more common as more literature explains its benefits, especially in spinal surgery.

Keywords: *neurosurgery, neuronavigation, spine surgery*

Introduction

Neuronavigation is a navigation system that helps neurosurgeons in planning, adjusting actions, and providing navigation during the surgical process using three-dimensional (3D) imaging from CT, MRI, or C-arm, complete with virtual visualization of the instruments used during surgery.[1] Neuronavigation is currently commonly used worldwide as a technology that optimizes surgical outcomes and reduces surgical morbidity, especially in neurosurgery.[3] It is known that more than 2,300 healthcare facilities worldwide use neuronavigation systems.[1] In Indonesia, the use of navigation systems in neurosurgery was still relatively rare, and no literature had been found that explained the experience of using navigation systems in neurosurgery.

The radiation exposure received by both the patient and the surgeon during spinal surgery could have long-term health effects. The research by Theocharopoulos *et al*. showed that the radiation exposure for a spine surgeon was fifty times higher than that for a hip and knee surgeon. Many studies explained that the use of navigation systems had significantly lower radiation exposure compared to fluoroscopy procedures. A cohort study with a sample size of 40 patients undergoing posterior lumbar fusion reported an effective radiation dose of only 0.4 mGy with the navigation system, which was lower compared to the fluoroscopy group, which had 5.03 mGy.

The safety and efficiency levels of pedicle screw placement with the use of navigation were better compared to freehand techniques or fluoroscopy-guided procedures. Research conducted by Amiot et al. described an error rate of 15.3% in placing 544 pedicle screws from T5 to S1 with the freehand technique, which was much higher compared to the use of a navigation system, which had an error rate of only 5.4% for placing 294 pedicle screws. Research by Yu et al. on the placement of 2,062 pedicle screws in the lumbar and thoracic regions found that only 4.6% of the screws penetrated the pedicle >2 mm with the use of navigation, which was much lower compared to the freehand technique, which had an error rate of 16%. Additionally, the operation time for placing pedicle screws with the navigation system was significantly faster compared to the freehand technique.[5]

The navigation system can be used in most spinal surgeries, such as tumor resection, minimally invasive spine surgery (MISS), and spinal revision surgery. Three-dimensional images taken using CT, MRI, or C-arm before the surgery begins are synchronized with the patient's actual anatomy and dynamically visualize the relationship between the positions of various surgical instruments and the surrounding anatomical structures. [3,4] The advantages of using neuronavigation include shortening the operation time by quickly and accurately locating the target lesion, making smaller skin incisions to minimize bleeding, leading to faster healing of the surgical wound, and being very helpful for patients with unclear anatomical variations or bone malformations. [2,3,7]

The indications for using spine navigation are:

a. Spinal trauma, including odontoid fractures, unstable Hangman's fractures, lower cervical spinal fractures, and thoracic and lumbar spinal fractures.
b. Degenerative pinal diseases, including cervical disc herniation, cervical spinal stenosis, cervical ossification of the posterior longitudinal ligament, thoracic ossification of the ligamentum flavum, lumbar herniation, lumbar spinal stenosis, and lumbar spondylolisthesis.
c. Spinal malformations, including cervical malformations, severe congenital spondylolisthesis, kyphosis, and scoliosis.
d. Spinal tumors, both primary and secondary, as well as intraspinal tumors.
e. Spinal infections, including spinal tuberculosis infections.

Contraindications to Consider Before Performing Surgical Procedures:

a. Having systemic diseases or comorbidities such as severe bleeding, cardiovascular problems, and respiratory issues.
b. Excessive mobility or instability in the spinal segment to be operated on can cause navigation errors.
c. The surgeon's inability to place a stable and rigid tracker.
d. System failure to calibrate or produce images correctly.[6]

The spinal cord is a very complex structure that can be easily damaged by surgical instruments, causing negative health impacts for the patient, even with minor damage. Possible impacts on the patient include paralysis in specific areas, loss of body sensation, and sexual dysfunction. The use of neuronavigation helps prevent these potential issues by increasing surgical accuracy and assisting neurosurgeons in precisely locating the target lesion. However, the use of neuronavigation must also be performed by experienced surgeons, as simultaneous visualization and surgery require a high level of concentration and precision.

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Case Report

Experience with the Use of Neuronavigation

The navigation system in spinal surgery has so far only been used in a few hospitals in Indonesia. There is not much literature that explains the experience of using navigation systems in spinal surgery, especially in Riau Province. This report will describe the first experience of using the navigation system in Riau Province in a case of thoracic canal stenosis.

A 53-year-old male patient, who worked as a palm oil farmer, came in complaining of weakness in both lower limbs. Examination revealed UMN paraparesis with motor strength of the lower extremities at 2. The patient experienced protopathic and proprioceptive disturbances consistent with thoracic dermatome 7 downwards, as well as urinary and fecal incontinence. Physiological reflexes were increased and pathological reflexes were positive. The patient underwent an MRI examination (Figure 1), which showed spinal cord stenosis at the level of thoracic discs VII-X. The patient was then diagnosed with thoracic canal stenosis at the level of vertebrae VII-X and planned for decompressive laminectomy and posterior stabilization with the assistance of neuronavigation.

a. b. c.

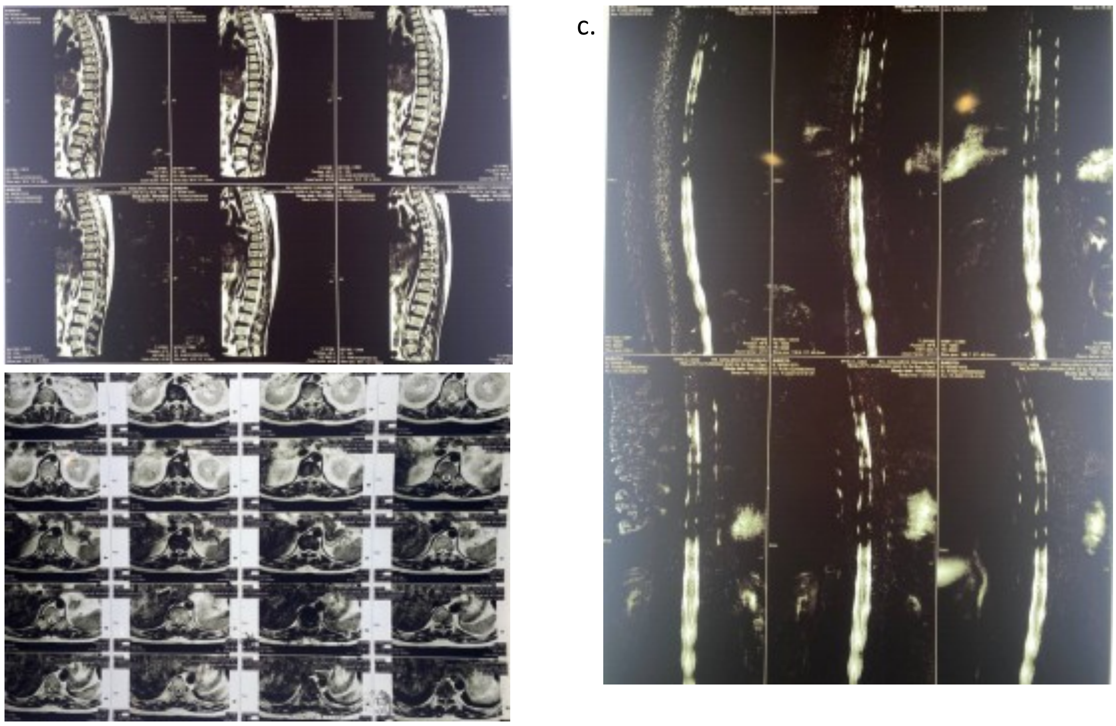

Figure 1. MRI of the spine showing (a) Sagittal, (b) Coronal, and (c) Myelography Sections.

Before the surgery began, three-dimensional images were taken of the patient in the operating room with the position corresponding to the intraoperative setup. These images were used by the operator to determine the surgical plan (Figure 2). The next step was to perform patient registration. There are two types of registration using the navigation system: automatic and manual registration. Automatic registration is possible if the scanner is equipped with special markers or a reference array. These markers are attached to the instruments and the patient's body, allowing them to be identified and synchronized using the scanner. The images are then automatically sent to the navigation system for registration. In the final stage of this process, the operator confirms the registration results. The automation process makes patient registration faster and more efficient. Manual registration is also a quick process, but compared to automatic registration, it involves some additional steps. Manual registration requires anatomical identification on the bone surface, such as the spinous process or vertebral lamina. Mapping is done on the posterior vertebral surface using a pointer, and then the navigation system matches the patient's accurate orientation and position to the preoperative images. At the time the surgery on the patient in this report was performed, the navigation system at Arifin Achmad General Hospital was still in the demo stage, so the registration technique used was manual because the C-arm was not yet connected to the navigation system (Figure 3).

The following were the SOPs for spine navigation: (1) select the spine menu from navigation, (2) choose the spine navigation procedure (spinal fusion/pelvic), (3) select the patient data to be processed, (4) set up the 3D model, (5) set up the planning (entry and target points for pedicle screw placement), (6) determine the registration points on the CT Scan/3D model, (7) attach the patient reference to the spinous process, (8) perform instrument registration to the patient reference, (9) verify the registration, (10) navigate.

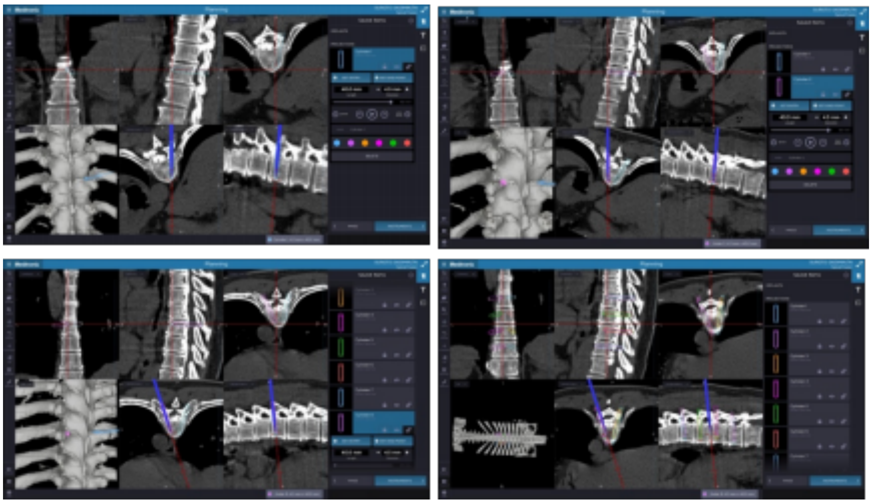

Figure 2. The stages of surgical planning for the patient, to determine the nearest and safest boundary of the lesion area.

(a) (b)

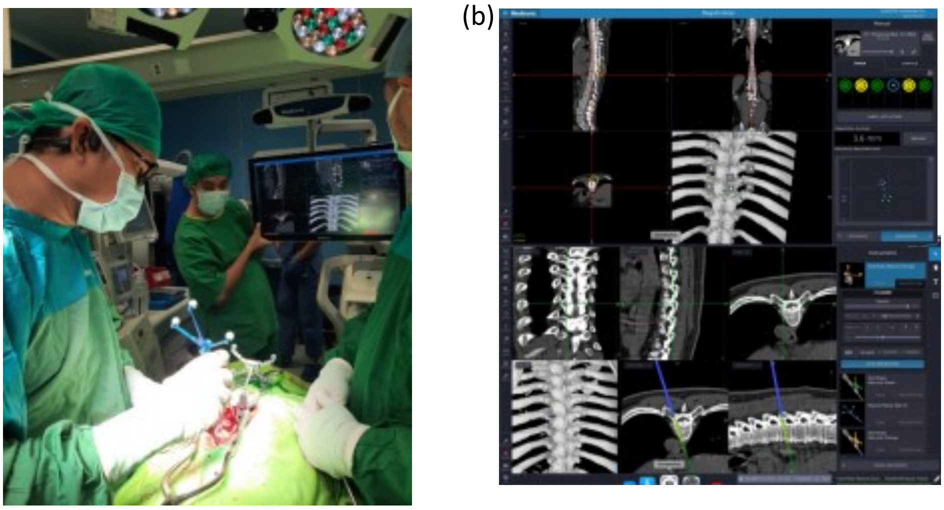

Figure 3. The stages of patient registration; (a) The operator created a mapping of the anatomical structure, (b) The 3D display on the navigation system.

After registration was completed, the operator could begin the navigation stage. The surgical instruments were dynamically displayed on the monitor screen, allowing the operator to estimate the distance of the instruments to important anatomical structures (Figure 4).[7]

(a) (b) (c)

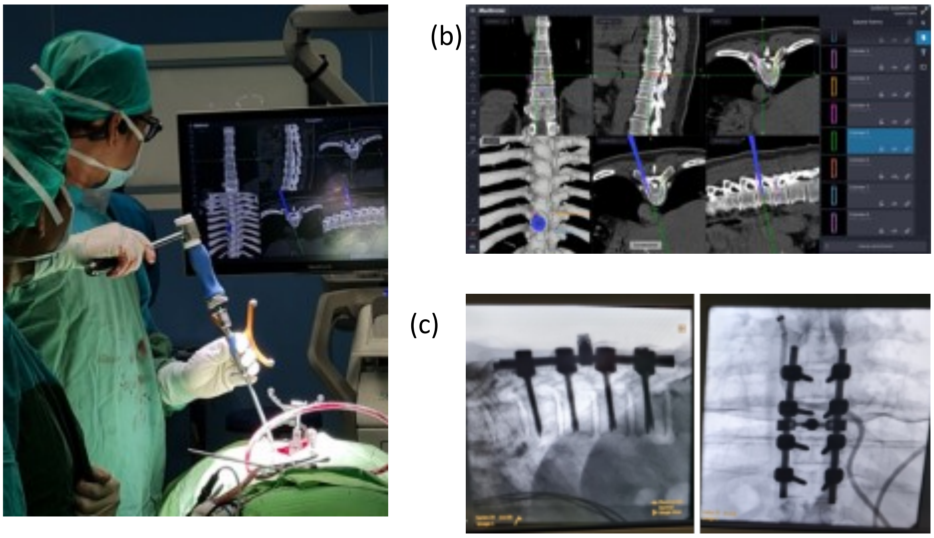

Figure 4. The stages of intraoperative visualization or navigation: (a) the operator used instruments dynamically with the aid of navigation on the monitor, (b) 3D display of the anatomical structures, (c) the result of the procedure.

Discussions

Pros and Cons of Using Spinal Navigation

The use of spinal navigation had many benefits, including improving surgical accuracy and reducing radiation. However, this technology had a steep learning curve, causing some surgeons to prefer using fluoroscopic techniques for thoracic-lumbar surgeries, while the navigation system was primarily used for the placement of pedicle screws.

Some experts believed that the smoothness of operations using the navigation system depended on the operator's proficiency with the technology, which could potentially extend the operation time and disrupt the surgical rhythm. Additionally, the navigation system had limitations in the field of view and could not be used in cases of lateral lumbar interbody fusion (XLIF) or oblique lumbar interbody fusion (OLIF).

A piece of literature compared the learning process over one year for navigation-assisted surgical techniques and freehand techniques, revealing that the mastery level of navigation use was comparable to that of freehand in terms of accuracy and the time spent on scanning and screw placement. It was noted that to enhance surgical accuracy, the frequency of tool use also needed to be increased. Operators were advised to have extensive experience with various cases to boost their confidence and comfort in using the navigation system.

Research showed that the use of navigation could speed up the time for screw placement and improve the accuracy of pedicle screw positioning. However, adjustments could still be necessary during intraoperative or postoperative phases, such as in obese patients, due to unclear imaging or potential system malfunctions.

The main goals of using spine navigation were: (1) to enhance patient safety, and (2) to provide better visualization for surgeons, thus improving accuracy and efficiency to achieve better surgical outcomes.[8]

Conclusions

The use of navigation technology in spinal surgery will be an innovation that will increase efficacy and patient safety. Its use is expected to become more common as more literature explains the benefits of this technology, especially in the field of spinal surgery.

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Declarations of competing interest

No potential competing interest was reported by the authors

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