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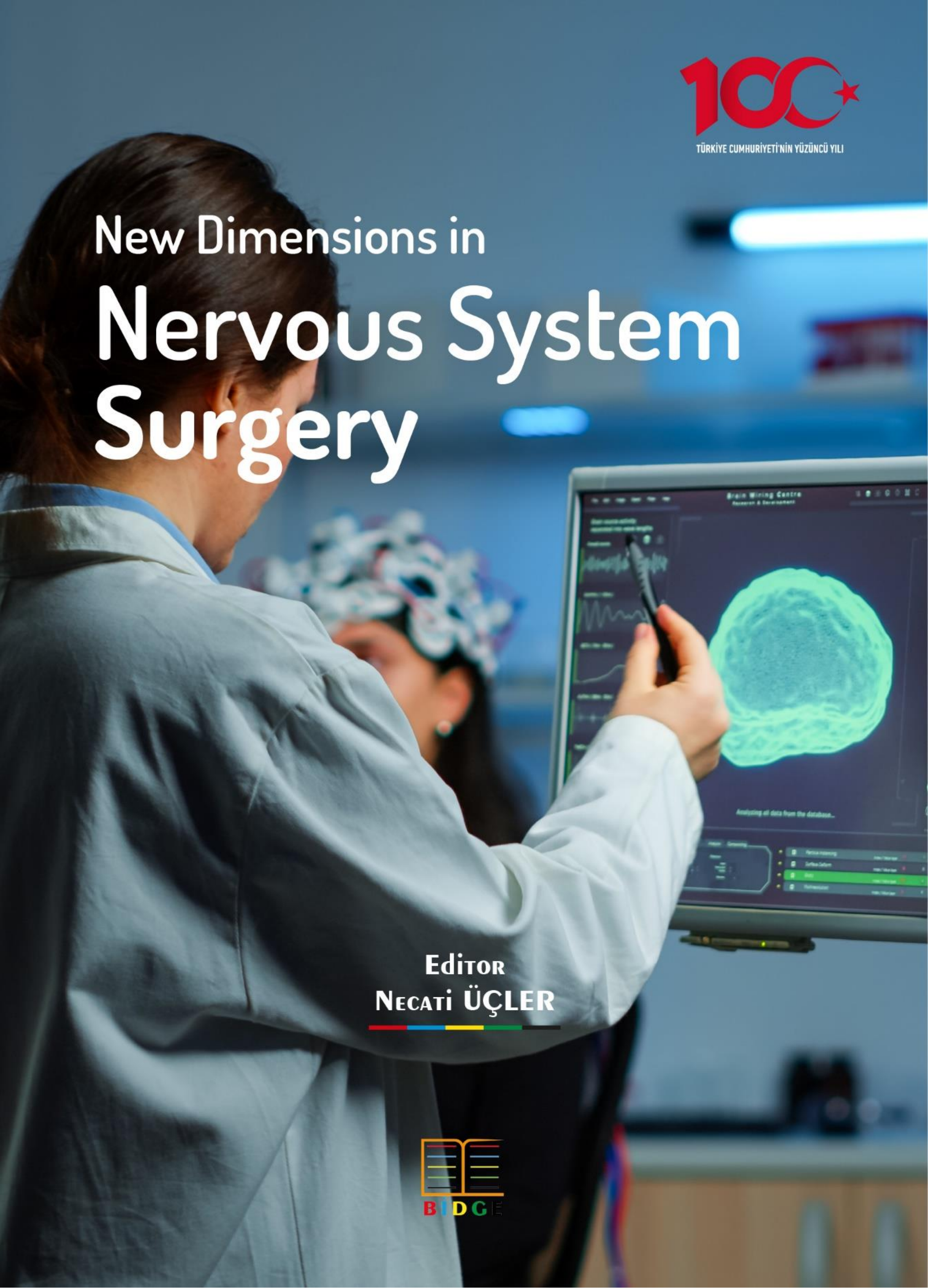
New Dimensions in Nervous System Surgery



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PREFACE

In Turkey, neurosurgery is officially known as neurosurgery, nervous system surgery, neurological surgery, neurosurgery and brain and spine surgery. In our country, there is still a lack of Turkish resources on neurosurgery for post-graduate general medical education, for the education of research assistants and for the specialization period. Education in the mother tongue is always more desirable. However, in higher education subjects, resources are generally in foreign languages. Those who work in these higher education branches continue to learn the subjects or diseases in their fields of interest from foreign languages, despite the efforts of Turkish resources in recent years. In medicine, different branches ask for help from each other in the form of consultation requests and it is even more difficult to find resources in the mother tongue for different branches. In fact, the nervous system consists of parts that cannot be separated or fragmented in any way. The nervous system works as a whole, and in case of disorders or diseases, the negative effects spread to the whole system. Compulsory rotations during residency training have been introduced to close the gap and disconnection in this area. From this point of view, in both student and resident education, the coordination of courses and practices in a complementary coordination will bring the student to the best point in understanding the subject, learning and therefore success. For this purpose, we prepared the book "New Dimensions in Nervous System Surgery" to be read in the native language of doctors from different medical branches. The chapters in the book were tried to be complementary to each other as much as possible in terms of subject and content. With these thoughts, we hope that our book will be an example for other branches of science and useful to readers.

Editor

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Contents

PREFACE 3
Contents 4
Anesthesia for Thoracic Spine Surgery 5
Mete MANİCİ 5
Doğa ŞİMŞEK 5
C1-2 Vertebral Fractures 23
Necati ÜÇLER 23
Ali NEHİR 23
Current Approaches in Minimal Invasive Spine Surgery 41
Aydın Sinan APAYDIN 41

CHAPTER I

Anesthesia for Thoracic Spine Surgery

Mete MANİCİ
Doğa ŞİMŞEK

Introduction:

The thoracic spine consists of 12 thoracic vertebrae, which have posterior convexity. It differs from the cervical and lumbar vertebrae in that it is more stable and immobile, due to an extra joint with their related rib, forming the rib cage. (1) Also, the spinal canal and the vertebral inter-spaces are the narrowest in the thoracic region. Beside the anatomical differences in the thoracic spine, thoracic spine procedures might have higher complication and morbidity rates due to proximity to vital organs such as the heart and the lungs, higher preoperative patient comorbidities, more complex and difficult surgical technique. Anesthesia management in thoracic spine surgeries is a rather risky and difficult process that requires attention. Therefore, it is vital to assess and manage the whole perioperative period by considering all the accompanying neurological, cardiovascular and respiratory compromises.

Increasingly complex surgical procedures over time have forced improvements in anesthesia techniques and pharmacology. High volume blood loss, long duration, complications related to surgical positioning and high incidence of moderate to severe postoperative pain are among the most important clinical obstacles during the anesthesia management of thoracic spine surgery. ERAS (Enhanced Recovery After Surgery) is a multimodal approach that includes up-to-date, evidence-based perioperative care strategies that reduces the length of hospital stay and complications. Currently, these protocols are also applied to patients who will undergo spinal surgery. With the use ERAS protocols for spine surgery, faster recovery, increased patient satisfaction, shorter hospital stays and reduced health care costs are achieved. (2,3)

Hence, comprehensive preoperative evaluation, safe and appropriate anesthesia induction and airway management, close follow up through the postoperative period to discharge, productive communication between the surgical and anesthesia team and a multidisciplinary approach is crucial for an excellent perioperative care.

Preoperative Evaluation:

All patients should undergo a detailed physical examination, laboratory screening and imaging before surgery. In order to minimize the perioperative risk, medical conditions which can improve should be consulted to an expert, necessary blood products should be reserved and intensive care unit support should be at hand if needed.

Evaluation of the mouth opening and neck movement in the preoperative period will allow the clinician to be prepared for difficult airway. Because of the thoracic deformities, thoracic spine surgery patients' airway patency, pulmonary function abnormalities and possible respiratory complications should be thoroughly assessed. Patients with limited pulmonary function may need prolonged postoperative mechanical ventilation. (4) The type of surgery can also have a significant impact on postoperative pulmonary status. (5) For example, patients which undergo one lung ventilation are more likely to have impaired postoperative pulmonary function.

A detailed cardiovascular evaluation should be carried out. Patients with scoliosis might have coexisting congenital heart diseases, heart failure and pulmonary hypertension. (6) Conditions such as intraoperative tachycardia and hypotension may cause detrimental consequences in those with coronary artery disease.

Significant surgical bleeding is often seen due to the long duration of surgeries and frequent history of extended use of non-steroid anti-inflammatory analgesics. Just the opposite, immobility in the perioperative period might cause deep vein thrombosis (DVT). Each patient should be evaluated and if needed, DVT prophylaxis initiated.

Type of premedication and whether premedication is necessary or not should be decided according to the patients neurological, hemodynamic and pulmonary status. Clinical trials show that preoperative 600 mg gabapentin provides mild sedation and reduces postoperative pain scores. (7) 0,5 mg alprazolam or 5 mg diazepam (0,05-0,2 mg/kg) is effective for preoperative anxiety when given per oral a night before. A small dose of intravenous midazolam (1-2 mg) can be used right before the procedure to provide amnesia and sedation.

Patients' preoperative conditions, concomitant diseases, neurological deficits, if any, should be well documented, all procedures to be performed on the patient should be described in detail and the patient must be well informed. After this, their consent should be obtained.

Monitoring:

Patients undergoing thoracic spine surgery, like any other surgery, should be monitored according to American Society of Anesthesiology's (ASA) standards, beginning with pulse oximetry, ECG, arterial blood pressure, capnography and body temperature. A more invasive monitoring plan should be performed in patients with serious comorbidities or who are expected to have complicated surgery with a risk for high volume blood loss and long duration of surgery. Thoracic spine surgery is usually performed with a posterior approach, which is technically easier than the anterior approach since it does not require opening the rib cage. All types of surgical instrumentation are expected to have higher surgical complications, as they might lead to more intraoperative bleeding and injury of the adjacent organs. Invasive arterial blood pressure (IABP) monitoring is very useful for instant assessment of blood pressure and repetitive arterial blood gas analysis, both of which helps to correctly interpret and manipulate hemodynamic status. A large central venous line is a necessary intervention in terms of rapid transfusion and, if necessary, vasoactive or inotropic agent infusion. It is also mandatory to monitor the body temperature, since a decrease in temperature can disrupt coagulation, as well as neurophysiologic monitoring. Hypothermia can also increase the rate of perioperative infection. Measuring urine output is an easy method and a good guide to assess renal perfusion, surgical bleeding and fluid management.

Neurophysiologic monitoring is required to monitor spinal cord function and reduce the perioperative neurologic injury. The simplest methods for assessing spinal cord function and nerve root damage are somatosensory evoked potential (SSEP), motor evoked potential (MEP), wake-up test and electromyography (EMG). Anesthetic agents can suppress SSEP signals. In the absence of neurophysiologic monitoring techniques, the incidence of motor deficit or paraplegia after scoliosis surgery was between 3.7 - 6.9%, while it has been observed that it could be reduced to 0.5% by intraoperative neurophysiologic monitoring. (8) Surgical injury or hemodynamic changes may cause neuronal damage. It is noted that SSEP and MEP monitoring are useful tools for monitoring spinal cord perfusion and function.

Induction of Anesthesia:

All thoracic spine surgeries are performed under general anesthesia, with a few exceptions (for example, spinal cord stimulator implantation), in which the patient will need to remain awake as part of the surgical procedure. Induction of anesthesia is provided with a combination of a hypnotic agent (propofol, ketamine, thiopental, etomidate etc.) with an opioid. After adequate ventilation is provided with a mask, nondepolarizing muscle relaxants (rocuronium, vecuronium, atracurium, etc.) can be administered to facilitate intubation. Advanced airway management techniques such as intubation without muscle relaxants, videolaryngoscope, fiber optic bronchoscope are used in patients who are considered to have difficult airway or difficult mask ventilation. Maintenance of anesthesia is achieved with a balanced anesthesia technique, which includes the infusion of opioids, muscle relaxants and volatile (sevoflurane, desflurane) or intravenous anesthetics. It should be noted that in the presence of spinal trauma and neurological deficits, doses of anesthetic agents should be reconsidered due to muscle loss, a decrease in the volume of distribution and albumin levels. Patients under high risk for neurologic deficits can be maintained mildly hypertensive during the surgery to reduce the risk of neurologic injury due to hypoperfusion and ischemia. Neuromonitoring is part of the surgical plan, a lower level of volatile anesthetics or total intravenous anesthesia is recommended to reduce the likelihood of suppressing the recorded potentials. Neuromuscular blockers disrupt motor evoked potentials and electromyography and should not be used during monitoring.

Patients with a history of opioid use may have tolerance to these drugs, and a higher dose may be required for titration.

Positioning:

Operating rooms with enough space should be preferred since a lot of surgical equipment is needed for thoracic spine surgery. After the induction of anesthesia, pneumatic compression devices should be applied and a urinary catheter should be inserted. In these patients, there may be a risk of venous air embolism, as the surgical site may remain above the heart level, so caution should be exercised during surgery. Positioning is very important to provide proper surgical field. The prone position is the most commonly used position for spine surgeries, while the right and left lateral decubitus positions are often used for the anterior approach, with the surgical side remaining on top. Most thoracoscopic surgeries are performed in the right lateral decubitus position next to azygos vein on the right side, since a larger area is visible than on the left side. During positioning, attention should be paid to the proper padding of pressure-sensitive areas such as bone protrusions, eyes, and peripheral nerves.

In patients with a planned anterior approach, a double-lumen endotracheal tube is used for one lung ventilation, the location of the tube should be checked again with a fiber optic bronchoscope after positioning. With positioning, the pressure on the rib cage increases the peak inspiratory pressure needed to reach a sufficient tidal volume, this can lead to hypoventilation. In these cases, ventilation with low tidal volume and high frequency can be applied. In case of emergency (e.g., cardiopulmonary resuscitation or repositioning of the endotracheal tube) a stretcher should always be available for the patient to be quickly placed in a supine position. In the prone position, if the operation is on the lower levels of the thoracic spine, the upper extremity should be abducted with an angle of ninety degrees or less without tension on the musculature, the upper limbs can be placed on the arm boards. In high thoracic spine surgeries, the arms should be kept in a neutral position tucked on the sides. In the anterior approach, the arms are placed on parallel arm boards on the side with caution not the abduct more than ninety degrees, the lower leg is flexed from the hip and knee and the upper leg is placed straight and supported with a pillow between the legs.

Thoracoscopic Approach:

In order to reduce the invasiveness of thoracic spine surgeries, the thoracoscopic approach has become frequent in recent years. The advantages of this approach are that because it is less invasive, it can lead to less blood loss, faster recovery and good pain control. The use of thoracoscopy in spinal surgery was introduced in Germany in the 1990s by Daniel Rosenthal et al., and in United States by Michael Mack and John Regan et al. (9-10) Paravertebral abscesses, enlarged paravertebral tumors in the thoracic cavity, primary or metastatic spinal tumors, vertebral fractures and thoracic disc hernias can be approached with thoracoscopy. In scoliosis surgery, thoracoscopic anterior approach can be performed in combination with a posterior approach.

The fact that the procedure is less invasive does not mean that anesthesia management will be easier. For visualization of the thoracic spine, one lung ventilation is required. Spinal deformities might cause restrictive respiratory function and these patients might not tolerate one lung ventilation. A thorough evaluation of coexisting diseases, physical status and especially cardiac and pulmonary function should be carried out. During surgery, there may be major hemodynamic changes, especially due to one lung ventilation. Therefore, all patients should be followed up with invasive arterial monitoring. The decision on the placement of a central venous catheter is similar to that in open thoracic vertebral surgical procedures and depends on the patient's condition before surgery, the invasiveness of the procedure, the expected blood loss as well as the need for vasoactive or inotropic agent infusion. If the subclavian vein or internal jugular vein is to be selected for the central catheter placement, the side where the thoracoscopic procedure will be performed should be preferred to prevent bilateral pneumothorax. The surgical procedure is usually performed in the right lateral decubitus position. Caution should be exercised in terms of complications that may occur due to the positioning. Since surgery is performed through small incisions between the ribs, pain is milder and easier to control with standard analgesics. Intensive care unit and hospital length of stay is shorter. There is a more aesthetic healing process. The disadvantages of thoracoscopy are that recognizing the tissues and adapting to its visuals under video assisted equipment requires a long time. Due to anatomical limitations, it is only possible to approach spine pathologies between T5 and T11 vertebrae levels. The surgical time is longer. It may be necessary to switch to open thoracotomy, especially with large vessel injuries and inability to treat bleeding via thoracoscopy.

Blood Transfusion and Fluid Management:

In recent years, perioperative management of fluid therapy has gained great importance with the use of ERAS protocols. (11) It is known that the ERAS spine protocol has an important role in faster recovery of patients, increasing patient satisfaction, shortening hospital stay and reducing health care costs. (3) Like other major surgical procedures, fluid management is considered to be an important component of perioperative care in thoracic spine surgeries. Patient and surgery-related factors such as age, length of surgery, high volume intraoperative blood loss, and prone or lateral positions may affect intraoperative fluid administration.

There are two main goals of fluid management during spinal surgery. These are maintenance of normovolemia and prevention of decrease in serum osmolarity. It is aimed prevent hemodynamic instability by maintaining normovolemia. By avoiding low serum osmolarity, development of tissue edema can be prevented. (12) The use of colloids is limited, as they can disrupt coagulation.

Thoracic spine surgeries are usually accompanied by high volume blood loss. Instrumentation, multi-level surgery, epidural vein damage and revisions greatly increase the risk of bleeding. It is reported that in patients without preventive measures, blood loss can be up to 2.8 liters, and the transfusion rate can be as high as 81%. (13) It has been shown that morbidity, mortality and hospitalization time increase in transfused patients due to massive bleeding. To limit blood and blood product transfusion, patient blood management strategies like; use of antifibrinolytic treatments such as tranexamic acid, aprotinin; specific positioning of the patient, normovolemic hemodilution, cell salvage (red cell protection), permissive hypotensive anesthesia and minimally invasive techniques have been developed.

Extubation:

When, where and how to end anesthesia after the surgery is an important decision depending on the length of surgery, patients' comorbidities, complications during the procedure, blood loss, muscle weakness or residual neuromuscular block. Mostly, the patient is extubated in the operating room at the end of the operation and transferred to his/her room after follow-up in the post anesthesia care unit. If any difficulty with airway is anticipated, considering re-intubation difficulty, the patient should not be extubated before regaining consciousness, spontaneously breathing and being able to protect their airway. The surgical position, administration of intravenous fluids and blood transfusions can cause facial and airway edema. Respiratory status should be carefully evaluated before extubation in patients who went through one lung ventilation. Patients with serious comorbidities before surgery and patients who had intraoperative complications (prolonged surgical time, massive bleeding, hypothermia etc.) can be transferred to intensive care unit. If the patient is to be followed up in an intensive care unit without extubation, the intensive care unit should be informed and preparations for mechanical ventilation and sedation should be made. Considering that a neurological examination is mostly going to be needed, sedation should be performed with short-acting agents.

Complications:

Many complications might occur during and after the surgery related both to the procedure itself and anesthesia. Postoperative 36 hours are the most important. Atelectasis being one of the most common. One lung ventilation, increased airway secretions and pain-related hypoventilation are risk factors for atelectasis. Other thoracoscopic spine surgery complications are massive blood loss, pneumonia, wound site infections, pulmonary embolism and chylothorax. Myocardial infarction due to hypoxia, hypovolemia and arrhythmias may occur. Pneumothorax may develop due to instrumentation. Neurologic deficits may occur due to surgical trauma or intraoperative ischemia of the spine. Neuralgia due to thoracoscopy can be seen. (14)

Pain Management:

Pain management is critical in thoracic spine surgeries and a multimodal pain management is the most appropriate method in terms of postoperative analgesia. As noted previously, pain might lead to hypoventilation which is a risk factor for atelectasis. So are the strong opioids which can cause respiratory depression. Patient controlled analgesia (PCA) devices prepared with small doses of intravenous opioids can provide pain free periods. It is known that analgesic doses of ketamine, which can be used in addition to intravenous opioids, reduce opioid consumption. Oral or intravenous acetaminophen has also been shown to reduce opioid consumption after surgery. Finally, it has been observed that gabapentin, when used through the whole perioperative period, reduces patients' pain scores and opioid consumption, but in addition to these benefits, side effects such as dizziness and sedation should be taken into account.

Local anesthetic infiltration is also a method that can be used. Dexmedetomidine and midazolam can be used as sedatives, and fentanyl or remifentanil may be used as analgesics in patients who have undergone thoracic spine surgery and are planned to be mechanically ventilated for prolonged period. It has been proven that dexmedetomidine provides less opioid consumption and has a lower incidence of delirium. (15)

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CHAPTER II

C1-2 Vertebral Fractures

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Introcution

The C2 vertebra, also known as the axis, is a critical structure in the cervical spine. Fractures of the C2 vertebra are relatively common, comprising approximately one-third of cervical spine

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fractures [1]. These fractures can be challenging to diagnose due to the absence of neurological deficits or easily identifiable radiographic findings [2]. Traumatic injuries to the C2 vertebra can result from various causes, including high-energy trauma, such as gunshot injuries [3], and rapid cervical flexion and extension, compression, or traction, which are common sequelae of head trauma [4]. Additionally, fractures of the C2 vertebra can lead to significant complications, such as cervical spondylolisthesis and spinal cord compression [5].

The management of C2 vertebral fractures is crucial for achieving positive outcomes and preventing secondary neurovascular deficits. Immediate surgical fixation, such as posterior C1–C3 fusion, has been shown to result in excellent outcomes without secondary neurovascular deficits in cases of traumatic complex C2 vertebral fractures caused by gunshot injuries [3]. However, the surgical approach to C2 vertebra fractures requires careful consideration, especially in pediatric patients, as cervical arthrodesis may limit growth potential or lead to secondary deformities [6].

The complex anatomy and the importance of ligaments in providing stability at the upper cervical spine region (O-C1-C2) require the use of various imaging modalities to evaluate upper cervical injuries (UCI) [7]. Furthermore, fractures affecting the lower cervical spine most commonly involve the C6, C7, and C5 vertebrae, highlighting the significance of understanding the distribution and characteristics of cervical spine fractures for effective management [8].

Fractures of the C2 vertebra present unique challenges in diagnosis and management, requiring a comprehensive understanding of the anatomical, biomechanical, and clinical aspects of these injuries to achieve optimal outcomes.

The etilogy of C1-2 fractures

The etiology of C1-2 vertebral fractures is multifactorial and can be attributed to various traumatic and pathological factors. Traumatic injuries, such as high-impact accidents, falls, and direct trauma to the cervical spine, are common causes of C1-2 vertebral fractures [9]. These fractures can also be associated with complex injuries, including rotatory subluxation, dens and articular facet fractures of C2, and anterior displacement of the C2 vertebral body [9][10]. Additionally, gunshot injuries have been reported to cause complex fractures of the C2 vertebra, leading to significant challenges in management [11].

Furthermore, the anatomical complexity of the upper cervical spine, including the C1-C2 region, poses a risk for vertebral artery injury during surgical interventions, such as posterior C1-C2 fusion and screw insertions [12][13]. The involvement of ligaments and joints in the upper cervical spine region also contributes to the complexity of these fractures and their management [14].

Pathological factors, such as osteoporosis, can also contribute to the etiology of C1-2 vertebral fractures. Osteoporotic fractures have been associated with an increased risk of subsequent fractures and mortality, highlighting the importance of understanding the underlying bone density and quality in the etiology of these fractures [15][16].

In addition, congenital anomalies, such as atlantoaxial deformities and anomalies of the atlas, have been reported as potential contributors to the etiology of C1-2 vertebral fractures [17][18]. Furthermore, the presence of anomalies in the vertebral artery at the craniovertebral junction can predispose individuals to unstable C1 burst fractures, adding to the complexity of the etiology of these fractures [19].

Overall, the etiology of C1-2 vertebral fractures is influenced by a combination of traumatic, pathological, and anatomical factors, necessitating a comprehensive understanding of the underlying mechanisms to guide effective management and treatment strategies.

The types of C1-2 fractures

The classification of C1-2 vertebral fractures encompasses a range of complex patterns and classifications, each with distinct characteristics and implications for management. These fractures can be broadly categorized into several types based on their specific anatomical features and associated injuries.

One common classification system for C1-2 vertebral fractures is the Anderson and D'Alonzo classification, which categorizes odontoid fractures into three types. Type I fractures involve the tip of the odontoid process, type II fractures occur at the base of the odontoid process, and type III fractures extend into the body of the axis vertebra Shaaban et al. [20]. This classification system provides valuable insights into the location and severity of odontoid fractures, guiding treatment decisions and prognostic assessments.

Another important type of C1-2 vertebral fracture is the traumatic C1-2 rotatory subluxation, often associated with dens and bilateral articular facet fractures of C2. This complex injury presents unique challenges in management due to the rotational displacement and the involvement of multiple structures within the upper cervical spine [21].

Additionally, atlanto-occipital dislocations (AOD), commonly referred to as internal decapitations, represent another fracture pattern involving C1. These severe injuries require careful evaluation and specialized treatment approaches due to the potential for catastrophic neurovascular complications [22].

Furthermore, Hangman's fractures, which involve the bilateral pedicles of C2, are classified based on the severity of the fracture and the degree of displacement. Type I Hangman fractures are stable and often amenable to conservative treatment, while type II fractures are unstable and may require surgical intervention [23].

Moreover, C1 fractures can also be subcategorized based on the specific anatomical involvement and associated injuries. For instance, C1 anterior arch fractures, which can occur spontaneously or as a postoperative complication, require tailored management strategies to address the unique biomechanical considerations and potential instability resulting from these fractures [24].

In summary, the types of C1-2 vertebral fractures encompass a spectrum of complex patterns, including odontoid fractures, rotatory subluxations, AOD, Hangman's fractures, and specific anatomical subtypes. Understanding the distinct characteristics and implications of each type is essential for guiding precise treatment decisions and optimizing outcomes for patients with these challenging injuries.

The diagnosis of C1-2 fractures

The diagnosis of C1-2 vertebral fractures is a critical aspect of effective management and treatment. Various methods and technologies are employed to accurately identify and assess these fractures, ensuring appropriate interventions and prognostic evaluations.

One approach to diagnosing vertebral fractures involves the use of imaging modalities such as dual-energy X-ray absorptiometry (DXA) and vertebral fracture assessment (VFA). DXA is recommended for the diagnosis of osteoporosis and assessment of future fracture risk, providing valuable information on bone mineral density (BMD) and potential fracture risk Maricic [25]. VFA, derived from DXA, is specifically designed to assess vertebral fractures, enabling the identification of prevalent vertebral deformities and the prediction of subsequent vertebral fractures [26][27].

Furthermore, radiographic diagnosis plays a crucial role in identifying and confirming the presence of osteoporotic vertebral fractures in clinical practice. Radiography, including routine chest radiography, has been recognized as a potential screening method for the diagnosis of osteoporosis-related vertebral fractures, highlighting its utility in early detection and intervention [28][29].

Computer-aided diagnosis (CAD) has emerged as a significant research subject in medical imaging and diagnostic radiology, offering the potential to enhance the accuracy and efficiency of vertebral fracture detection. CAD systems have the capacity to aid in the early detection of osteoporosis and vertebral fractures, contributing to timely pharmacologic intervention and risk reduction [30][31].

In addition to imaging techniques, clinical assessment and recognition of vertebral fractures are essential for accurate diagnosis. However, underreporting of vertebral fractures on routine radiography has been identified as a challenge, emphasizing the need for better awareness and training in the definition of vertebral fracture to improve diagnostic accuracy [32][33].

Overall, the diagnosis of C1-2 vertebral fractures involves a multidimensional approach, encompassing imaging modalities, computer-aided diagnosis, and clinical recognition. The integration of these methods is crucial for accurate identification, assessment, and management of vertebral fractures, ultimately contributing to improved patient outcomes.

The treatments of c1-2 vertebral fractures

Treatment options for C1-2 vertebral fractures encompass a range of approaches, including conservative management, surgical interventions, and rehabilitation strategies. The choice of treatment depends on the specific characteristics of the fracture, associated injuries, and the patient's overall health status.

Conservative management, such as external orthoses, is often effective for stable fractures, providing support and promoting healing Mead et al. [25]. Additionally, nonoperative treatment may include analgesic use and back bracing to alleviate pain and facilitate recovery [26]. However, for unstable fractures or those associated with neurological deficits, surgical intervention may be necessary to achieve stabilization and prevent further complications.

Surgical treatments for C1-2 vertebral fractures include various approaches, such as anterior and posterior fixation, C1-C2 fusion, and pedicle screw fixation. Both anterior and posterior approaches have shown high rates of fusion, with neither approach demonstrating clear superiority [27]. Posterior C1-C2 fusion, such as the Harms technique, has been reported as an effective method for stabilizing the atlantoaxial complex [28]. Furthermore, segmental C1-2 fusion and C1-C2 fixation have been utilized to address complex injuries involving the upper cervical spine [29][30].

In cases of traumatic fractures, open reduction and posterior C1–C2 fixation may be performed to restore alignment and provide stability [29]. Additionally, temporary fixation can be used as a salvage treatment for odontoid fractures with an intact transverse ligament in cases of failure of, or contraindication to, anterior screw fixation [31]. Furthermore, dynamic fluoroscopy can aid in differentiating subtypes of craniocervical dissociation and guide treatment decisions [32].

Rehabilitation plays a crucial role in the recovery process for patients with C1-2 vertebral fractures. Physiotherapy interventions, including manual techniques and exercise interventions, have been shown to have an important treatment role, improving quality of life, balance, and reducing the risk of subsequent fractures in individuals with osteoporotic vertebral fractures [33][34].

In summary, the treatment of C1-2 vertebral fractures involves a multidisciplinary approach, encompassing conservative management, surgical interventions, and rehabilitation strategies tailored to the specific characteristics of the fracture and the individual patient's needs.

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CHAPTER III

Current Approaches in Minimal Invasive Spine Surgery

Aydın Sinan APAYDIN

Introcution

Spine fusion surgery was first performed by Albee in 1911 and Hibbs in 1912 and became more frequently preferred in the second half of the 20th century. (1) Minimal Invasive Spine Surgery (MISS) was first used in the literature by Kambin in 1991 with the arthroscopic microdiscectomy method. (2) With modern surgical technologies such as digital fluoroscopy, microcopy, high-resolution endoscopy, tissue retractors and minimally invasive surgical instruments, minimally invasive approaches have become common.In recent years, minimally invasive surgical procedures have become widespread in the field of brain and neurosurgery, as in every field. Minimally invasive surgical techniques have become more preferred in the last 20 years, particularly in spine surgery. The main advantage of minimally invasive surgical techniques is faster recovery with less soft tissue damage and shorter hospital stays. (3) With minimally invasive surgical techniques, soft tissue damage and postoperative pain decrease, hospitalization time decreases, patient mobilization occurs earlier, the amount of bleeding during surgery decreases, the risk of post-surgical infection decreases, economic costs decrease, and due to minimal incisions, aesthetic appearance and patients can return to their everyday lives earlier. (4) In the last twenty years, minimally invasive spine surgical approaches have been described for every area of the spine and have begun to be used as a surgical option. (5-6) MISS procedures include operative microscopy, cannulated screw technology, and exceptional surgical equipment such as tubular retraction systems, endoscopy, fiber optic lighting, and camera systems when needed. Correctly choosing and using these technologies is the most crucial step in implementing MISS procedures. As in traditional spine surgery, spinal fusion and accurate and adequate decompression of neural elements are at the forefront in MISS.

Principles of Minima Invasive Spine Surgery

The most important principle of MISS is to minimize damage to the soft tissue surrounding the spine during surgery. (7) It has been reported that since it minimizes the damage to soft tissue during surgery, it reduces the need for postoperative analgesics and narcotics and shortens the patient's length of stay. (8) In minimal spine surgery, the most suitable area is determined using fluoroscopy with the help of a small incision in the skin. This stage has the most critical role in reaching the underlying spinal pathology. Before the retractor system is inserted through the skin with fluoroscopy, the soft tissue pathway to the spinal cord is opened using sequential dilators to minimize tissue damage rather than cutting or resectioning the tissue. After dilation, the tubular retractor is advanced towards the spinal cord with the help of fluoroscopy and its position is secured. Light and magnification of the image are critical during surgery with tiny incisions. The operative microscope provides the best visualization in most minimally invasive spine surgeries.

Spinal instrumentation

With the development of percutaneous cannulated pedicle screw systems through the posterior approach, the locations and trajectories of the pedicles are determined under fluoroscopy, and the screw-rod fixation system is realized. (7) A large Jamshidi needle is passed through the pedicles with the C-arm guide, and then a guidewire is inserted. (Figure 1) The guidewire is then used to prepare and place the cannulated pedicle screws. It is not a fusion technique but only a spinal instrumentation procedure with a MISS method.

Figure 1: Fluoroscopy image shows the entry of the tip of a Jamshidi needle (arrow) into the pedicle of the L5 spinal corpus.

The dynamic stabilization technique has recently been developed as an alternative to fusion in degenerative spine treatment. In this technique, fusion is not performed; only percutaneous stabilization is performed with a dynamic screw and dynamic rod system. Pedicular guide wires are sent to the vertebrae to be fixed from both sides. Suitable screws are sent over this guide wire. Thus, the single-distance posterior instrumentation system is placed percutaneously into the spine by making a total of 6 small (1-2 cm) incisions without paravertebral muscle dissection (Figure 2).

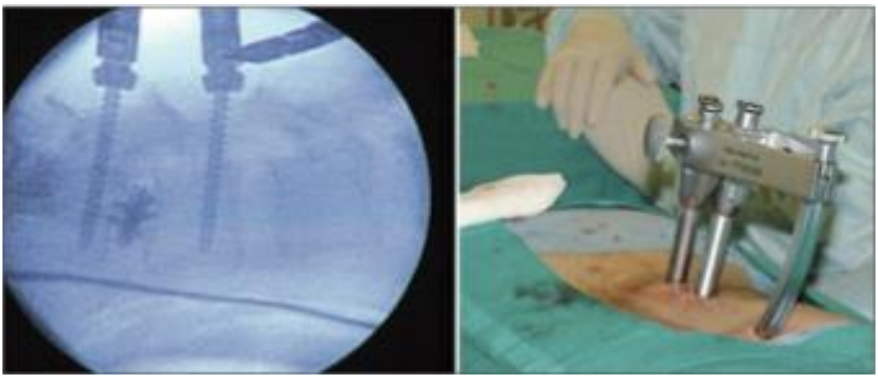

Figure 2: Screws placed posteriorly percutaneously are fixed with a rod placed percutaneously.

Decompression techniques

Pathologies such as degenerative spine disease, spinal canal stenosis or disc herniation can be treated with MISS. Simple decompressive surgery generally has fewer complications and constitutes a suitable starting point for the surgeon in the assistant stage in MISS after adequate training and practical skills on cadavers. It should not be forgotten that although MISS decompressions are performed through small skin incisions, correct and proper decompression is important in obtaining good clinical results.

Before surgery, the surgical procedure should be well planned, and radiological examinations should be carefully examined to determine the exact localization of neural tissues and the operative strategy. In cases such as disc herniation, the placement of sequestered fragments should be planned according to the pedicle and disc space. A simple laminotomy performed on the disc fragment will allow it to be removed and decompress the neural elements. In cases such as disc herniation, the patient is in the prone position and is placed on the fluoroscopy operating table so that anteroposterior and lateral radiographs can be seen. From 8-10 cm lateral to the midline, the cambin triangle is reached at an angle of approximately 45°, and the disc is reached through it. (9) Bilateral percutaneous endoscopic discectomy and decortication can be performed (Figure 3).

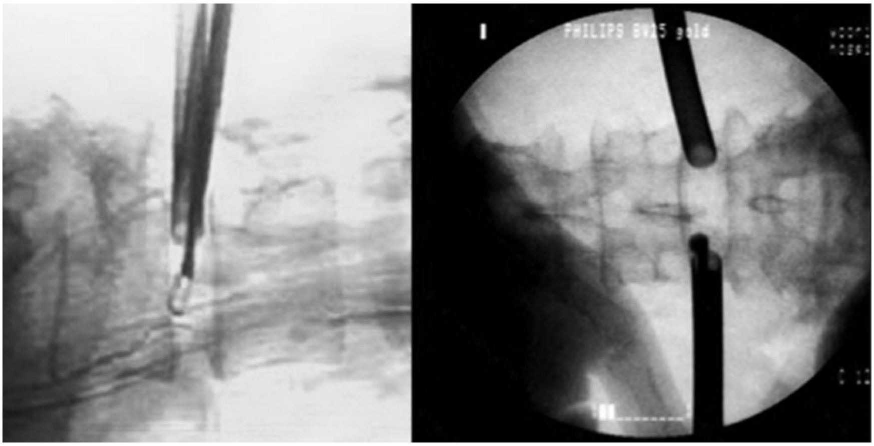

Figure 3: Endoscopic discectomy and decortication.

In spinal stenosis cases, identifying the specific location of the stenosis within the spinal canal is crucial. Laminoplasty is often the preferred approach for addressing bilateral stenosis through a single-sided access point. Initially, wide hemilaminectomy and medial facet resection are performed to decompress the ipsilateral side along with the laminoplasty technique. Placing a tube under the lamina allows for a view of the opposite side of the spinal canal, facilitating the procedure's angle to perform contralateral medial facetectomy.

This technique involves using a long, slender, high-speed diamond tip motor along the midline of the spinal canal to reach the contralateral side. During decompression with the motor, leaving the ligamentum flavum intact safeguards the underlying dura from the motor's action. Once the decompression is performed with the motor, the ligamentum flavum is then removed to ensure clear visibility of the dura, confirming adequate decompression has been achieved.

Spinal arthrodesis

MISS enables various types of arthrodesis procedures, such as posterolateral fusion, posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), and anterior lumbar interbody fusion (ALIF). Among these, posterolateral fusion stands as the most straightforward technique, involving sequential dilation of paraspinal muscles. This method relies on a tubular retractor placed on the transverse process, facilitated by an expandable retractor system that grants easy access to both superior and inferior transverse processes. The procedure involves dissecting soft tissues from the intertransverse space, followed by decorticating the transverse process pars interarticularis and facet joint. This prepares the intertransverse region and facet joint for fusion using an appropriate bone graft material. After bilateral percutaneous endoscopic discectomy, the end plates are decorated with appropriate surgical instruments, a bone graft can be placed between the vertebral bodies and the interbody instrumentation system can be identified (Figure 4). In this way, the entire fusion process is performed through a tube. The rate of pseudoarthrosis has been reported at various rates between 2.9% and 30%. (10) Percutaneous transpedicular fusion is needed to strengthen the system.

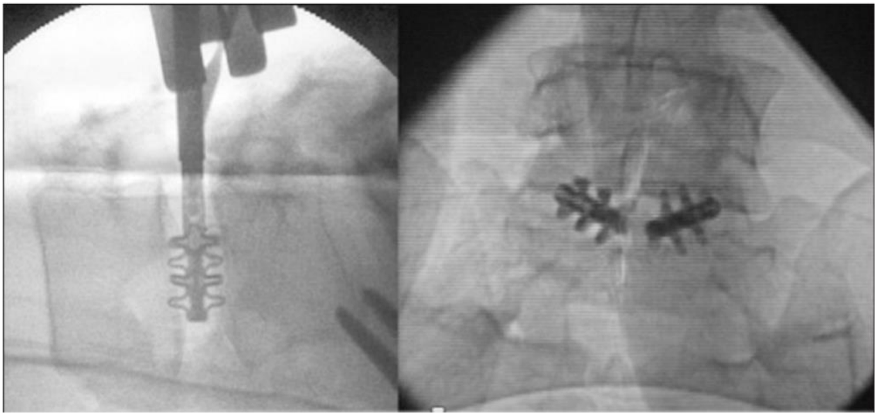

Figure 4: Posterolateral endoscopically placed intervertebral instrumentation system. (AP and lateral view).

Different interbody support cages are made of materials like titanium, poly-ether-ether ketone (PEEK), or bone allograft. Choosing an appropriately sized cage is crucial to support the disc space, while the remaining area requires sufficient graft material to optimize fusion alongside the cage. During minimally invasive transforaminal lumbar interbody fusion (TLIF), an incision from midline to lateral facilitates quick access to clean the opposite side of the disc space. Posterior interbody fusion procedures should always be accompanied by spinal instrumentation for support.

Anterior lumbar interbody fusion (ALIF) can be carried out using laparoscopic methods or via open procedures like small-diameter transperitoneal mini-laparotomy. ALIF ensures precise disc space reconstruction, minimizing risks of neural or epidural damage. Following ALIF, percutaneous pedicle screws may be inserted for spinal cord stability. For fusing L2–3, L3–4, or L4–5 disc spaces, the lateral transpsoas approach is preferred. Its advantages include avoiding vascular mobilization and reducing damage to the hypogastric plexus or postoperative ileus (7).

Extreme lateral interbody fusion (XLIF) is preferred in spinal disorders such as low-grade spondylolisthesis, lumbar disc herniation and degenerative scoliosis. (11) The patient is placed on the operating table in the left lateral decubitus position by fluoroscopy. With MISS, a cage is placed in the space after discectomy. Then, the patient's position changes, and percutaneous fixation is performed. Plexus damage is observed in 13-28% of cases. (12)

Than et al. highlighted the objective of minimally invasive surgery, targeting a correction of pelvic incidence lumbar lordosis discrepancy by 10 degrees and SVA by 5 mm (13). Furthermore, Mummaneni et al. introduced an enhanced decision-making algorithm for assessing the suitability of MISS techniques in individuals with spinal deformities (14).

Percutaneous vertebroplasty-kyphoplasty

While conservative and surgical treatments can be applied alone or combined in the treatment of spinal fractures, The primary aim is anatomical reduction, preventing spinal deformity, reducing pain, restoring spinal height due to compression fracture in the spine, and enabling the patient to return to daily activities more quickly with stable fixation and early mobilization.

It may also be preferred as a pain treatment in osteoporotic spinal fractures and tumour metastases to the spine that do not respond to conservative treatment. The most disturbing symptom seen in patients is pain. The pain progressively intensifies, and its effect decreases or disappears entirely during rest and sleep. Neurological findings are frequently detected in thoracic vertebral body metastases. Urinary-fecal incontinence and paraplegia are the most common findings. The prognosis is poor in rapidly developing symptoms (15,16).

The spinal cord is entered percutaneously and transpedicularly with the help of fluoroscopy, and specially designed bone cement is injected into the spinal cord for mechanical support and pain relief. The amount and location of cementum are checked by imaging with instantaneous fluoroscopy.

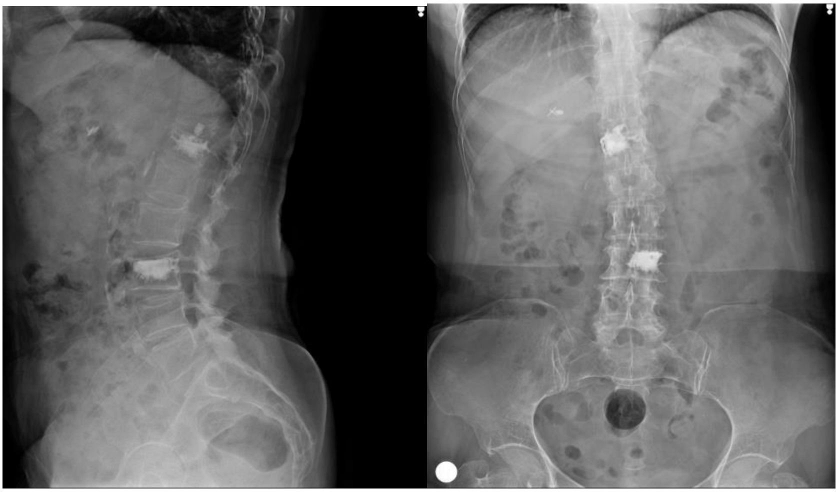

Figure 4: Percutaneous vertebroplasty-kyphoplasty (sagittal and axial)

Challenges in MISS

The adoption of MISS techniques presents a significant challenge for surgeons accustomed to traditional open procedures. It involves navigating limited visibility, operating within narrow spaces, and demands a high level of skill with specialized tools and technology (17). Learning this technique follows an S-shaped curve—initially slow, then rapid progress, finally reaching a plateau. While specific numbers for the learning curve in cervical spine surgery are limited, studies suggest that 15 to 72 cases in the lumbar region are needed to reach proficiency (18). The rate of improvement hinges on factors like training, mentorship, access to advanced tools, imaging, years of experience, and case complexity.

Mastering the learning curve relies on a deep understanding of 3D anatomy. Real-time navigation aids surgeons in visualizing intricate anatomy, offering better surgical outcomes. Jiang et al. found that navigation during ALIF procedures didn't significantly alter operation times or fusion rates. Enhancing this process involves understanding direct and relational anatomy, using navigation assistance, practicing on cadaver models or real cases, and receiving effective mentoring (19). In evaluating cost-effectiveness, 45 meta-analyses compared MISS with open TLIF and PLIF procedures. Clinical outcomes showed no significant difference, but cost analyses from nine studies revealed reduced care costs for minimally invasive procedures (20).

The rise in minimally invasive procedures has increased radiation exposure due to fluoroscopy use for precise anatomical detection. Patients undergoing minimally invasive TLIF procedures encounter higher radiation than those with open TLIF procedures. Similarly, surgical personnel face increased radiation exposure in specific body areas during minimally invasive lumbar microdiscectomies (21). However, integrating CT navigation systems can mitigate radiation exposure by providing detailed patient anatomy visualization.

Developments and the Future in MISS

MISS has significantly evolved, especially with advancements in intraoperative imaging. This progress addresses the limitations of 2D fluoroscopy, enhancing visualization during procedures. Recent advancements in navigation techniques, particularly 3D image-guided navigation systems based on preoperative CT scans or intraoperative imaging, have improved surgical outcomes as adjunctive tools in MISS.

Integration of intraoperative imaging units like the isocentric C-arm and O-arm with modern navigation systems offers real-time 3D imaging. A meta-analysis comparing 2D fluoroscopy to 3D navigation revealed a remarkable 99% reduction in pedicle screw fracture rates within the 3D group (22).

Major medical technology firms have introduced innovations like the Augmedics XVision Spine, wearable head-up technology projecting images onto the surgical field. Augmented reality has demonstrated 94-97% accuracy in pedicle screw fixation (23).

The advent of 3D printing has expanded possibilities in MISS, enabling the creation of intricate biomodels and patient-specific devices. These not only aid in preoperative evaluations and surgical planning but also effectively mitigate increased complication rates and prolonged hospital stays (24).

Compared to traditional open surgery, MISS offers several advantages, including reduced postoperative pain, blood loss, infection risk, and hospital stays. With experience, it can be applied across various degenerative spine conditions. While similar techniques are employed, there are nuanced differences in surgical instruments and approaches between minimally invasive and open procedures. Expect a learning curve when transitioning to MISS.

Note: *The images used in the manuscript are taken from Assoc. Prof. Dr. Salim Şentürk's archive.*

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New Dimensions in Nervous System Surgery

In Turkey, neurosurgery is officially known as neurosurgery, nervous system surgery, neurological surgery, neurosurgery and brain and spine surgery. In our country, there is still a lack of Turkish resources on neurosurgery for post-graduate general medical education, for the education of research assistants and for the specialization period. Education in the mother tongue is always more desirable. However, in higher education subjects, resources are generally in foreign languages. Those who work in these higher education branches continue to learn the subjects or diseases in their fields of interest from foreign languages, despite the efforts of Turkish resources in recent years. In medicine, different branches ask for help from each other in the form of consultation requests and it is even more difficult to find resources in the mother tongue for different branches. In fact, the nervous system consists of parts that cannot be separated or fragmented in any way. The nervous system works as a whole, and in case of disorders or diseases, the negative effects spread to the whole system. Compulsory rotations during residency training have been introduced to close the gap and disconnection in this area. From this point of view, in both student and resident education, the coordination of courses and practices in a complementary coordination will bring the student to the best point in understanding the subject, learning and therefore success. For this purpose, we prepared the book "New Dimensions in Nervous System Surgery" to be read in the native language of doctors from different medical branches. The chapters in the book were tried to be complementary to each other as much as possible in terms of subject and content. With these thoughts, we hope that our book will be an example for other branches of science and useful to readers.

BIDGE