Unilateral Biportal Endoscopic Spine Surgery

Basic and Advanced Technique

Dong Hwa Heo
Ji Yeon Kim
Don Young Park
Cheol Wung Park
Choon Keun Park
Editors

Second Edition

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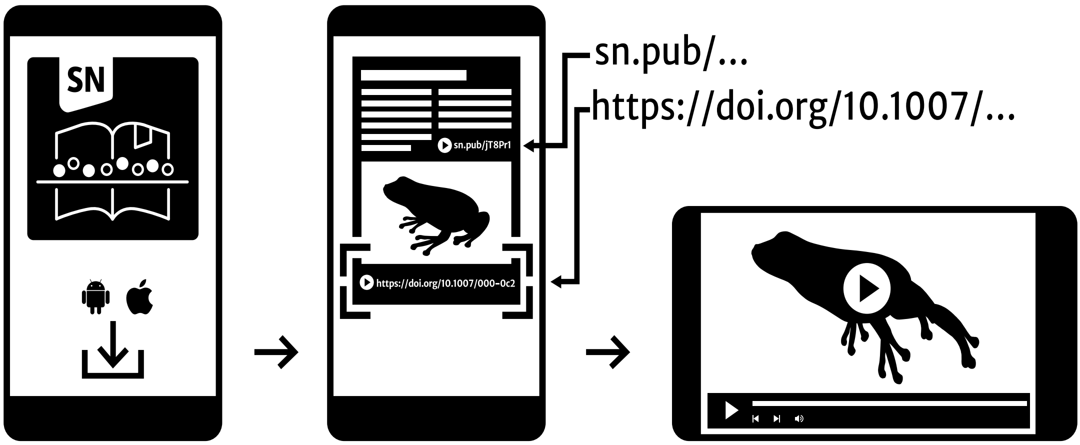

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Congratulatory Address

I was first drawn to biportal endoscopy after encountering Dr. De Antoni's 1996 article on the technique. It had been an unknown concept before then, holding similarly unknown potential. But I was still intrigued, and I decided to directly evaluate biportal endoscopy and its applications in 2001 with Dr. Gaffar. Rather than giving me a preliminary introduction as one would expect from such an evaluation, however, I was immediately convinced this technique would be revolutionary for spine surgery patients. The technique was simply that impressive in its possibilities. From that moment on, I introduced it to Korea and made it my life's ambition to continue developing the technique and its instruction. But I still could have never envisioned the extent to which the surgery has evolved and popularized. In the past, it was natural to only visit the United States or Europe to learn advanced techniques in spine surgery. Now, it is not a surprise to head to Korea instead, specifically for the advancements in unilateral biportal endoscopy among other techniques.

The first edition of the textbook *Unilateral Biportal Endoscopic Spine Surgery* provided an introduction to the technique regarding its basic concepts and basic methods. It was so complete in its goals that I had not expected a second edition to come so soon. But it coincides with the acceleration of biportal endoscopy's popularity in both its academic and practical sense. The second edition, thus, expands upon the first edition by including recent insights, papers, etc., which should necessarily be included for today's study of unilateral biportal endoscopic spine surgery.

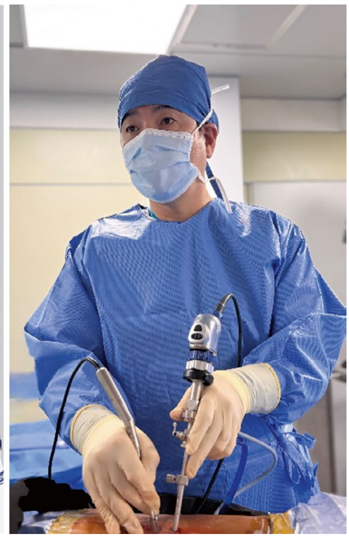
I give my heartfelt thanks and congratulations to the publishing of the second edition of *Unilateral Biportal Endoscopic Spine Surgery* and all those who have worked together to make this a reality.

Sincerely,

Neurosurgery, Burgeel Royal Hospital
Abu Dhabi, United Arab Emirates

Jin Hwa Eum

Preface



The field of spine surgery has witnessed remarkable advancements over the years, with minimally invasive techniques emerging as a transformative force in how we approach spinal disorders. Among these innovations, unilateral biportal endoscopic spine surgery stands out as a groundbreaking development that combines precision, efficiency, and patient-centered care. This textbook represents a culmination of efforts to compile a comprehensive resource dedicated to this evolving technique, providing a foundation for surgeons worldwide to understand, adopt, and refine their skills in unilateral biportal endoscopic approaches.

As the main editor of this work, it has been my privilege to collaborate with a distinguished group of experts who have generously shared their insights, experiences, and knowledge. Each chapter is crafted to bridge the gap between theory and practice, offering readers a balanced blend of detailed anatomical guidance, step-by-step procedural instructions, and informative surgery videos. I am deeply grateful to the contributors, whose dedication and expertise have been instrumental in shaping this book. Their collective efforts reflect the spirit of collaboration and the shared vision of advancing patient care through minimally invasive techniques. I would also like to thank the publishers and editorial team for their unwavering support and meticulous attention to detail throughout this project.

It is my hope that this textbook will inspire and empower readers to embrace the potential of unilateral biportal endoscopic surgery, pushing the boundaries of what is possible in spine surgery. By doing so, we can collectively improve outcomes, reduce patient recovery times, and set new standards for excellence in surgical care.

Thank you for joining us on this journey into the fascinating world of unilateral biportal endoscopic spine surgery. May this textbook serve as a valuable companion in your professional endeavors.

Sincerely,

Seoul, South Korea Dong Hwa Heo

Preface

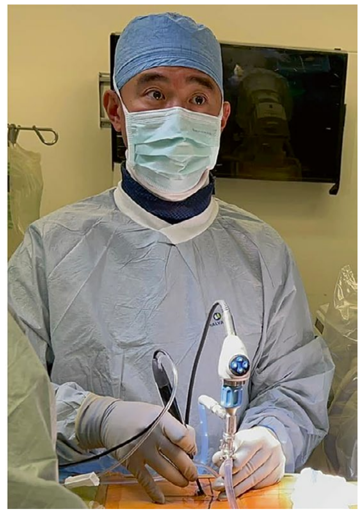

As an endoscopic spine surgeon, I have dedicated my career to advancing spinal endoscopic systems, performing surgeries on conditions ranging from cervical to thoracic myelopathic diseases. My journey began with the full endoscopic transforaminal approach, evolving into a preference for uniportal endoscopic lumbar decompression surgery.

A pivotal moment came when I encountered Unilateral Biportal Endoscopic (UBE) surgery at a symposium. The scalability and flexibility of UBE surgery, allowing the use of both hands through independent portals, revolutionized my practice and overcame the limitations of uniportal techniques. This led me to develop new surgical methods for degenerative spinal diseases, such as lumbar multifocal stenosis decompression and cervical open-door laminoplasty, achieving outstanding outcomes.

The second edition of this UBE textbook provides a comprehensive guide, including fundamental concepts, well-designed surgical techniques, and complication prevention strategies. Enhanced with high-quality videos and figures, it aims to inspire and educate both seasoned surgeons and newcomers. I hope this book helps you explore and embrace the transformative potential of UBE surgery.

Seoul, South Korea Ji Yeon Kim

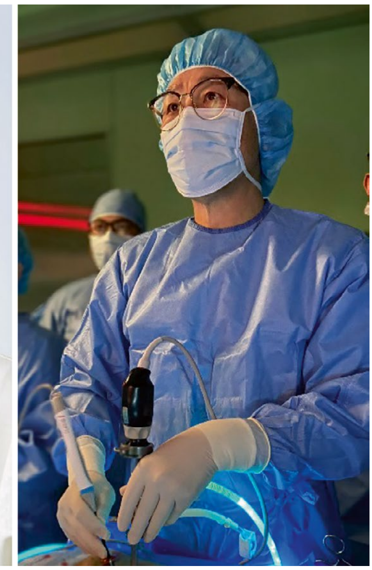
Preface



One of the greatest honors of my career was being included on this esteemed panel of editors for the Unilateral Biportal Endoscopy 2nd Edition textbook. I would like to give special thanks to the editor-in-chief, Dr. Dong Hwa Heo, for this incredible opportunity. UBE has truly changed the direction and trajectory of my career and learning from the UBE masters, many of whom have contributed to this textbook, which has been so fulfilling and gratifying. We are standing on the shoulders of giants. When I first saw UBE with my own eyes, I was completely blown away by the power and versatility of this ultra-minimally invasive technique. After spending the first 10 years of my career performing open and tubular surgeries, I quickly realized how relatable UBE is, making the learning curve shallower and shorter. I believe that UBE is the next evolution of spine surgery and will be the dominant form of minimally invasive spine surgery in the near future. I'm quite certain that our patients are the first to sing its praises because of UBE's excellent outcomes and safety profile. UBE is a perfect complement to future applications of emerging technologies, such as advanced spinal robotics, augmented reality, and artificial intelligence. I am so excited to see the future of spine surgery with UBE and I am certain that the techniques described in this textbook will be a critical element of that future. I know that this textbook will push the envelope of UBE with the most state-of-the-art techniques.

Irvine, CA, USA Don Young Park

Preface



It is a great privilege to present the second edition of the UBE (Unilateral Biportal Endoscopy) textbook. As one of the main editors and the current president of the Korean Minimally Invasive Spine Surgery Society (KOMISS), I would like to extend my heartfelt congratulations to everyone involved in this monumental achievement.

This new edition reflects the significant advancements made in UBE, showcasing even more refined and innovative techniques. As the nation that pioneered UBE, Korea continues to lead the way in its practical applications, and this textbook exemplifies our commitment to elevating the quality and precision of UBE procedures.

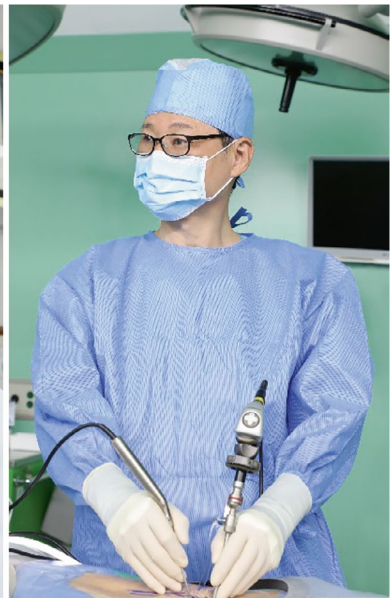
I would especially like to express my deepest gratitude to our Chief Editor, Dr. Dong-Hwa Heo, whose vision and leadership have been instrumental in guiding this project from conception to publication. I am also deeply thankful to all contributors for their invaluable dedication and hard work, which have made this textbook a comprehensive and essential resource for spine surgeons worldwide.

This edition not only marks a significant step forward in the field of endoscopic spine surgery but also serves as a beacon for those looking to further their expertise in minimally invasive techniques. I am confident that this textbook will continue to inspire innovation and excellence in the field for years to come.

Sincerely,

Daejeon, South Korea Cheol Wung Park

Preface

The paradigm of spine surgery has evolved from traditional open surgery to microscopic surgery, and further to minimally invasive spine surgery (MISS), aiming to reduce surgical burden while preserving normal anatomical structures. MISS has been conspicuously developed over the last three decades to reduce damage to normal spinal structures during operations and improve functional outcomes. MISS can be divided into two main streams: (1) spine surgery using a tubular retractor system and (2) endoscopic spine surgery (ESS). MISS using a tubular retractor was introduced to address spinal degenerative pathologies with minimal injury to the posterior paraspinal muscles and ligamentous complex. I have already adopted and performed these two MISS techniques, achieving favorable clinical outcomes. However, the tubular system for spinal surgery has been restricted due to its limited corridor and narrow operative field. Despite the development of new endoscopic approaches or techniques, initial ESS had many limitations due to restricted usage of surgical instruments, blurred visions from old camera systems or bleeding, high radiation exposure, and a steep learning curve. To overcome these pitfalls, the demand for new MISS techniques has continuously increased.

Despite the initial report of arthroscopic lumbar discectomy using two portals by Dr. De Antoni, this approach did not become widely known for a long time. In the 2000s, pioneering Korean spine surgeons initiated two-portal endoscopic surgery, terming it unilateral biportal endoscopic spine surgery (UBE). With advantages such as providing a clean and clear magnified surgical view and usage of familiar surgical equipment for most spine surgeons, the UBE has grown by lowering the entry barriers for ESS.

Initially applied to discectomy and decompression in the lumbar spine, the UBE has gradually expanded its operative indications to include decompression at cervical and thoracic spinal cord levels. Additionally, the UBE has proven effective in revision surgeries for recurrent lumbar disc herniation. The rapid and significant evolution of the UBE has prompted the need for an updated edition of the UBE textbook. This second edition aims to provide valuable insights not only for spine surgeons seeking to master the fundamentals of the UBE but also for those eager to advance their UBE techniques.

Several key physicians have contributed to the introduction and advancement of the UBE technique. I take immense pride in having collaborated on joint research with Dr. Jin Hwa Eum and Dr. Dong Hwa Heo at Leon Wiltse Memorial Hospital. These surgeons have played a pioneering role in the early development of UBE surgery. Dr. Dong Hwa Heo, the principal editor of this textbook, continues to dedicate himself to the advancement and dissemination of this procedure through rigorous education and training. Their contributions have been pivotal, and I anticipate that their ongoing efforts will significantly influence the future progress of UBE.

It is an honor to contribute to the preface of this second edition of the UBE textbook. I am grateful to the editors and authors of each chapter for their immense contributions. I hope that readers of this textbook will acquire the knowledge and skills to achieve the ultimate goals of MISS through the UBE.

Suwon, Gyeonggi, Republic of Korea Choon Keun Park

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Part I

Introduction

1 A Brief History of Unilateral Biportal Endoscopic Spine Surgery

Heeseok Yang and Jeong-Yoon Park

1.1 Introduction

Endoscopic spine surgery has evolved significantly from its initial application in lumbar disc herniation treatment to more complex procedures. The development of biportal and large-working-channel interlaminar endoscopic systems has expanded its indications to include lumbar central or lateral recess stenosis and foraminal stenosis. These advancements have made procedures such as endoscopic posterior laminotomy, laminectomy, and foraminotomy feasible, offering shorter hospital stays and faster recovery compared to traditional microsurgery. The evolution of biportal endoscopic techniques now allows for comprehensive bone work, including laminectomy and foraminotomy, across various spinal regions from cervical and thoracic to lumbosacral lesions. This broadens the range of conditions that can be treated endoscopically, including cervical central stenosis, cervical foraminal stenosis, thoracic disc herniation, and endoscopic fusion [1].

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1.2 History

1. *Initiation of biportal endoscopic spine surgery*

In 1996, De Antoni et al. introduced a technique using two independent portals for endoscope and instrument insertion [2]. Soliman published surgical results for lumbar disc herniation and spinal stenosis in 2013 and 2015, using biportal endoscopic techniques with independent portals, which is very similar to the current unilateral biportal endoscopic (UBE) method [3, 4]. The term "biportal" was used first in 2016, and "UBE" was introduced in articles published in Korea [5]. Increased experience of endoscopic spine surgery with UBE has led to an explosion of innovation, first in Korea. Currently, UBE is regarded as a crucial endoscopic spine surgery technique, applicable to all lumbar degenerative diseases including the cervical and thoracic spine.

2. *Brief history of unilateral biportal endoscopic spine surgery in Korea*

Abdul Gaffar presented "Lumbar Disc Excision by Midline Extradural Endoscopy" in 2001 at the American Academy of Orthopaedic Surgeons (AAOS) conference. Korean Dr. Young Chul Choi, after visiting Abdul Gaffar in 2002,

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implemented UBE in Korea with Jin Hwa Uhm. In 2003, Jin Hwa Eum presented on biportal endoscopic lumbar discectomy at a Korea-Japan conference. In 2013, Jin Hwa Eum and Sang Kyu Son presented on various UBE applications at international conferences. Dr. Son also led the first UBE workshops in Korea in 2013. The world UBE society was organized in 2017 and has contributed to the development and popularization of UBE procedures through its academic activities.

1.3 Study and Advancement of UBE

1. *Safety*

Unilateral biportal endoscopic (UBE) spine surgery is a minimally invasive procedure involving the use of irrigation fluid to maintain a clear surgical field. Stable water dynamics during endoscopic spine surgery are crucial for surgical success and patient outcomes. Several studies emphasize the importance of controlled irrigation fluid dynamics in endoscopic spine surgeries. The placement and appropriate length of the cannula are crucial factors in maintaining stable water dynamics during UBE. Physical characteristics like BMI (body mass index) also significantly impact water pressure [6, 7]. Radiofrequency (RF) devices are essential in UBE spine surgery for soft tissue dissection and bleeding control. A study evaluates the safety of RF by measuring the temperature changes in the epidural space during biportal endoscopic lumbar decompressive laminotomy. They concluded that the use of RF in biportal endoscopic lumbar surgery is potentially safe, provided that RF application is limited in duration and power and continuous saline irrigation is maintained [8].

2. *Learning curve*

Several studies aimed to evaluate the learning curve and complications of UBE spine surgery including lumbar disc herniation, lumbar spinal stenosis, posterior cervical foraminotomy, and lumbar interbody fusion [9–13]. A learning curve represents the rate at which a person gains proficiency in a skill or task over time. In surgical contexts, it describes the number of cases required for a surgeon to achieve a level of performance that is stable and proficient. Cumulative sum analyses showed that the learning curve plateaued after 20–89 cases depend on studies and early phase complications were higher compared to the later phase. They suggested that reducing the learning curve and minimizing complications in UBE spine surgery require comprehensive training programs that include theoretical knowledge, simulation training, and mentorship by experienced surgeons [9–13].

3. *Clinical comparisons, systematic reviews, meta-analyses, and randomized controlled trials (RCTs)*

Comparative analyses add valuable insights into the management of lumbar disc herniation and spinal stenosis in emphasizing the potential benefits of UBE spine surgery in reducing postoperative complications and enhancing recovery outcomes [14, 15]. Across systematic reviews, several common themes and opinions emerge regarding the efficacy, safety, and overall benefits of UBE spine surgery. UBE consistently shows significant improvements in patient pain scores, functional outcomes, and overall quality of life. The UBE technique is effective in treating lumbar stenosis and provides reliable decompression, and the minimally invasive nature of UBE translates into less muscle damage, reduced intraoperative blood loss, and shorter hospital stays. Patients benefit from faster recovery times and lower postoperative pain compared to traditional open surgeries. UBE has a favorable safety profile with low complication rates. While complications such as dural tears and nerve injuries can occur, they are relatively infrequent and manageable with proper surgical techniques and postoperative care. These systematic reviews and meta-analyses provide valuable insights for spine surgeons, highlighting the advancements in minimally invasive spine surgery and supporting informed decision-making in the management of degenerative spinal disease [1, 16, 17].

Endoscopic lumbar interbody fusion has overcome initial limitations by adopting a posterolateral approach similar to minimally invasive transforaminal lumbar interbody fusion (TLIF) using tubular retractor. This method allows for direct neural decompression and large cage insertion, enhancing surgical outcomes. Clinical comparisons, systematic reviews, and meta-analyses demonstrate that UBE fusion is an effective and potentially superior technique compared to traditional open and minimally invasive TLIF, particularly in terms of patient recovery and overall clinical outcomes for lumbar degenerative diseases with growing evidence [18]. Several randomized controlled trials (RCTs) aim to assess whether the biportal technique offers better clinical outcomes and reduced postoperative complications compared to traditional methods and demonstrate the effectiveness and potential advantages of biportal endoscopic surgery in treating lumbar herniated disc and lumbar spinal stenosis [19–22].

4. *Cervical and thoracic spine*

Posterior cervical foraminotomy is an effective surgical technique for relieving nerve root compression. Clinical comparison studies highlight the advantages of biportal endoscopic techniques in terms of lower complication rates and better midterm clinical outcomes. The inclinatory surgical route used in endoscopic techniques is beneficial for preserving the facet joint while achieving adequate decompression [23, 24]. Several technical reports offer promising alternatives to traditional surgery for patients with cervical spondylotic myelopathy with bilateral decompression and biportal endoscopic approach for cervical laminoplasty [25, 26].

The ipsilateral biportal approach for thoracic spine decompression and fusion technique described in the 2012 paper by Said G. Osman and colleagues presents a minimally invasive approach to treating thoracic disc herniation [27]. While the technique offered several potential benefits, various technological and clinical factors contributed to its slow adoption. As technology advanced, training improved, and more evidence accumulated supporting its efficacy and safety, the technique may have gained more traction. The ossification of the ligamentum flavum (OLF) in the thoracic spine can cause significant thoracic myelopathy, leading to severe neurological deficits with thoracic disc herniation. Traditional treatment involves decompressive laminectomy with or without fusion. However, this conventional approach is often associated with extensive destruction of the posterior ligamentous complex and potential facet joint injury, leading to various complications. Several papers introduce a biportal endoscopic technique for posterior thoracic decompression as an alternative method, emphasizing its advantages, procedural steps, and potential complications [28–31].

5. *Bibliometric analysis*

The bibliometric and visualization analysis provides valuable insights into the global research landscape of UBE, highlighting the global distribution of endoscopic spine surgery (ESS) research, with China, South Korea, and the USA leading in publications. Studies identifies key contributors, emerging trends, and research hotspots, offering a comprehensive overview of the field's development [32, 33].

1.4 Future of UBE

The future of minimally invasive spine surgery lies in the continued development and integration of advanced surgical techniques and emerging technologies. Endoscopic spine surgery, with its expanding indications and improving outcomes, will play a significant role. Robotics, AR, and VR will further enhance precision and safety in spinal surgeries. The field of minimally invasive spine surgery (MISS), endoscopic spine surgery, and UBE is poised for significant growth and transformation, driven by innovation and a focus on improving patient care [34].

1.5 Conclusion

The unilateral biportal endoscopic (UBE) spine surgery has evolved to address a wider range of spinal conditions with less trauma and faster recovery compared to traditional surgeries. The growing global adoption of biportal endoscopic spine surgery techniques has been driven by patient demand for less invasive procedures and the potential for reduced hospital stays and recovery times. Overall, the future of UBE spine surgery appears promising with ongoing advancements in technology and techniques that aim to improve patient outcomes and procedural efficiency.

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2 The Basic Concept, Setting, and Instruments of Unilateral Biportal Endoscopic Spine Surgery

Dal-Sung Ryu and Jeong-Yoon Park

2.1 Introduction

The conventional surgical technique has shown excellent clinical results in treating various kinds of spine disease. However, it has been closely associated with complications such as cosmetic issues due to scarring, paraspinal muscle damage, and chronic postoperative lower back pain. To overcome these drawbacks, a surgical technique using a tubular retractor has been widely adopted for procedures ranging from simple decompression to fusion. Furthermore, an endoscope that allows access to the lesion through a single portal has been developed. The first-generation endoscopes primarily focused on removing disc herniations through the body's natural pathways like the neural foramen or interlaminar space. The clinical outcomes after endoscopic surgery were highly successful. Not resting on these achievements, the full endoscope has continued to evolve, now incorporating drills for bone work. This another advancement has expanded the scope of surgery to include the treatment of spinal stenosis through internal decompression, and full endoscopic fusion is also being attempted. Despite these advancements in endoscopic spine surgery, the high cost of equipment, relatively narrow field of view, limited instrument maneuverability, and steep learning curve mean that mastery of these techniques, comparable to conventional open surgery, remains rare. To address the limitations of traditional endoscopy, the unilateral biportal endoscopy (UBE) technique has been developed. UBE has gained significant popularity and is now widely used around the world.

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2.2 The Concept of UBE

The UBE, short for unilateral biportal endoscopy, is a type of endoscopic surgery that allows treatment of lesions on both sides while the surgeon stands on one side of the patient. It is sometimes classified as "endoscopy-assisted surgery." UBE is often used interchangeably with biportal endoscopic spine surgery (BESS), and while there are some differences in the detailed concepts, the overall surgical approach is almost same.

The most important concept in UBE is the use of two separate portals that create a triangulation. In full endoscopy, a single portal is used for endoscope insertion, and instruments like drills and forceps are inserted through the endoscope itself into

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the body. In contrast, UBE, similar to laparoscopy, uses a viewing portal for endoscope insertion and a separate working portal for instrument insertion. This setup allows the instruments to work directly in front of the camera, forming a triangulation. Fluid is supplied through a tube connected to the endoscope, circulating within the working space to flush out obstructive substances like blood and bone debris. These materials are then expelled through the working portal as outflow.

For right-handed surgeons, the endoscope is held in the left hand, while instruments are manipulated with the dominant right hand, allowing for precise and unrestricted operation. Unlike the abdomen or knee joint, the vertebra does not have an internal cavity or free space. To begin UBE surgery, after cutting the fascia, a muscle detacher is used to carefully separate the multifidus muscle from the lamina with minimal damage. Once the endoscope is inserted and fluid is introduced, hydraulic pressure creates a working space within the natural gap between the multifidus muscles. This approach minimizes periosteal dissection and virtually eliminates traction or crushing injuries caused by retractors during surgery. The high-definition camera provides excellent resolution, and continuous irrigation keeps the surgical field clear, offering a better view of the structures than high-resolution microscopes. Additionally, the endoscopic view closely resembles that of microscopic surgery, making it easier for surgeons to adapt due to the familiar surgical anatomy.

2.3 Classification of Endoscopic Spine Surgery

According to the consensus nomenclature for endoscopic spinal procedures developed by the AOSpine minimally invasive spine surgery (MISS) taskforce [1], UBE is categorized as endoscopy-assisted surgery (Fig. 2.1). However, this classification, which is limited to decompression and fusion, does not adequately capture the diverse range of current UBE procedures. Therefore, there is a need to establish a consortium of relevant experts to develop a more detailed and comprehensive consensus.

2.4 Why We Do UBE?

UBE is a novel surgical technique that takes the advantages of both conventional microscopic surgery and endoscopic surgery. One of the most significant benefits of UBE is its versatility due to high maneuverability. Unlike full endoscopy, biportal endoscopy allows instruments to access the surgical field externally to the endoscopic view, which greatly reduces restrictions on access. Consequently, standard instruments used in open spine surgery can be freely handled within the clear endoscopic view. This allows for extensive decompression, effectively relieving nerve compression. For example, the use of a chisel, which is limited with full endoscopy, can significantly reduce surgery time and achieve safer decompression. Additionally, this versatility translates into cost-effectiveness concerning equipment acquisition. Instruments commonly used in orthopedic shoulder arthroscopy can be utilized directly, enabling hospitals with existing equipment to commence surgeries immediately.

The high degree of flexibility in the UBE surgical techniques leads to a wide expansion of surgical indication. Full endoscopic spine surgery can be performed at the cervical or thoracic cord level, previously considered infeasible. There have been successful cases reported of spinal cord tumor removal and laminoplasty with UBE, which were once thought to be beyond the capabilities of traditional methods [2, 3]. Attempts have also been made to perform fusion surgery using full endoscopic techniques. However, the trans-Kambin approach has not adequately addressed concerns about nerve root injuries. Additionally, transforaminal approach with full endoscope is performed by only a few masters due to its steep learning curve. In contrast, biportal endoscopic transforaminal lumbar interbody fusion has been shown in several studies to provide comparable clinical outcomes to classical transforaminal lumbar interbody fusion

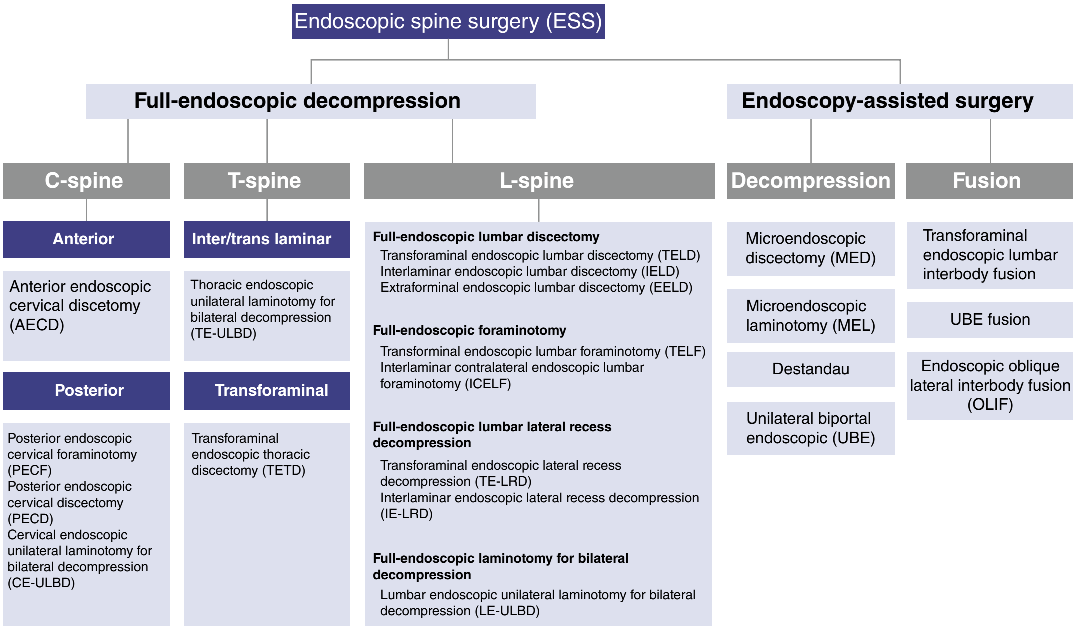

Fig. 2.1 Summary of current spinal procedures using endoscopic visualization. (Adapted from Hofstetter et al. [1])

techniques while reducing postoperative back pain and estimated blood loss (EBL) [4].

Once familiar with endoscopic visualization and coordinating hand movements, the learning curve is relatively short because it becomes similar to traditional surgery. According to Li et al., proficiency in full endoscopic discectomy was achieved after 40 cases for surgery targeting lumbar disc herniation, whereas for UBE discectomy, proficiency was reached after 15 cases [5]. This difference may be attributed to the fact that UBE allows surgeons familiar with conventional surgery to approach the anatomy in a similar manner, unlike full endoscopy, which presents unfamiliar anatomical structures. Furthermore, after initial level marking, UBE requires minimal radiation exposure because X-ray imaging is unnecessary once surgeons recognize anatomical landmarks. Surgery can proceed without the need for fluoroscopy during the procedure. This stands in contrast to full endoscopy procedures that require continuous fluoroscopy to confirm anatomical landmarks throughout the surgery.

2.5 Concerns Over the Failure to Start UBE

Surgery can become more challenging due to the mismatch between surgeon's dominant hand and the left-right approach direction. For example, for a right-handed surgeon, operating from the left side of a prone-positioned patient is easier. Starting surgery from the patient's right side can sometimes pose challenges due to differences in the angles of endoscopy and the angle of surgical instruments through the working portal. However, this is a common challenge faced by beginners. It can be easily overcome with accumulated experience through adjustments in incision placement and utilization of various instruments.

Theoretically, UBE helps maintain a clear surgical field by delaying bleeding with water pressure during the procedure, ultimately aiding in hemostasis. However, in the real practice, accurately assessing actual bleeding loss can be challenging, as any increased bleeding may mix with the irrigation fluid and be flushed out. Given the short operation times and less invasiveness of most decompression surgeries, this issue has minimal clinical significance. However, in multi-segment decompression or biportal endoscopic fusion, hidden blood loss can become a clinical concern. If surgeons do not recognize this, it can put the patient at risk [6]. Therefore, it is important not to neglect this issue and to perform adequate bleeding control as needed during surgery. When concluding the procedure, it is recommended to reduce or stop the irrigation to identify and control any active bleeding sites before finishing the surgery.

For beginners, a dural tear can be quite alarming and is one of the most common reasons for converting to open surgery. Dural injury rates range from 1.8% to 13.2%, which is comparable than those in conventional microscopic surgery [7]. These injuries are typically associated with the use of Kerrison rongeurs or pituitary forceps. To minimize the risk of a dural tear, it is advisable to completely dissect the structures to be removed or cut, ensuring they are taken out in larger pieces visible in the surgical field. Additionally, it is recommended to retain the ligamentum flavum as a protective barrier until the bone work is complete. Gentle dissection of the dura and the overlying ligamentum flavum allows natural adhesiolysis due to the irrigation fluid pressure, which can be beneficial.

However, once the dural tear occurs, it is best to immediately perform a direct suture repair or use non-penetrating titanium vascular anastomosis clips during the endoscopic procedure [8]. Because there is a risk of rootlet protrusion or pseudomeningocele formation, the problem should be definitively addressed under microscopy in an open surgery. UBE minimizes soft tissue dissection, which leads to fewer newly formed spaces during surgery, making tiny dural tears less prone to clinical complications. Additionally, a patch technique using fibrin sealant patch can be employed to address dural injuries smaller than 5 mm [9].

Park et al. reviewed 42 articles, analyzing 3673 biportal surgery cases. They included 2402 decompressions, 1056 discectomies, and 261 transforaminal lumbar interbody fusion (TLIF). The total complication rate was 7.79%, comparable to that of open surgery. The detailed complication profile is shown in Table 2.1 [10].

Table 2.1 Global complication profile after 3719 cases of biportal endoscopic surgery

Complication	Number (%)
Dural tear	83 (2.23)
Incomplete decompression	48 (1.29)
Epidural hematoma	141 (3.79)
Transient nerve root injury	9 (0.24)
Iatrogenic instability	6 (0.16)
Infection	3 (0.08)

2.6 Reducing the Learning Curve

For surgeons starting UBE, maintaining orientation is crucial for minimizing the learning curve. Quickly identifying anatomical landmarks after endoscope insertion greatly helps in reducing operation time. Since the view in UBE is similar to that in microscopic surgery, experienced microscopic spine surgeons tend to overcome the learning curve more easily. Loss of orientation can lead to unnecessary bone removal, excessive time consumption, and compromised segmental stability. This confusion can sometimes cause serious neurological damage, making the surgeon want to abandon UBE altogether.

To prevent this, it is essential to establish the top-bottom and left-right orientation externally before inserting the endoscope and ensure the endoscopic view has not rotated. After endoscope insertion, surgeons can reconfirm orientation by inserting a nerve freer through the working portal and checking its direction on the endoscopic screen. Soft tissues should be removed from the upper and lower lamina of the target decompression level, using tactile feedback to center the view before beginning bone work. Beginners may lose orientation during a laminectomy; in such cases, they should palpate the arrangement of the lamina and spinous process to realign before continuing bone work. During a laminectomy, maintaining orientation can be achieved by identifying landmarks such as the midline gap between the bilateral ligamentum flavum or the medial pedicle wall, ensuring appropriate decompression only where necessary.

It is also crucial to maintain appropriate water circulation to minimize surgical complications and complete the surgery within a short timeframe. Irrigation fluid enters the surgical field through the viewing portal and is then expelled through the working portal. Insufficient inflow results in low hydrostatic pressure within the surgical site, inhibiting natural muscle retraction and preventing the formation of a pocket, thus compromising the surgery. Conversely, inadequate outflow hampers effective irrigation within the surgical field, impeding visibility due to bleeding. Moreover, if only inflow occurs without sufficient outflow, muscle edema can result from hydrostatic pressure. Mostly, muscle edema increases with operative time but typically resolves over time [11]. Furthermore, excessive increases in water pressure can lead to elevated intracranial pressure (ICP) post-surgery, potentially causing headaches, seizures, or mental changes. Therefore, the optimal hydrostatic pressure is typically maintained between 20 and 50 mmHg, which can vary based on the distance between the irrigating saline bag and the working space. Hong et al. have suggested an average pressure of 16.66 ± 9.12 cmH_2O (12.25 ± 6.71 mmHg) under ideal conditions [12]. Surgeons must therefore focus on maintaining sufficient and continuous outflow to prevent the hydrostatic pressure within the working space from peaking. To achieve this, it is advisable to verify adequate outflow before commencing the actual surgery. Particularly in patients with a high BMI (body mass index) and longer out-pathway distances, using rigid cannulas like a semi-tubular retractor through the working portal can help secure outflow.

2.7 The Operating Room Setting

1. ***Operating team*** (Fig. 2.2)
   Surgeon, assistant, scrub nurse, circulating nurse, anesthesiologist, and radiological technician
2. ***Equipment*** (Figs. 2.2 and 2.3)
   Endoscopic system (endoscope, camera, light source, recording system, cable, and monitor) and drilling system, C-arm radiography and monitor, radiofrequency (RF) device, irrigating saline and pole, operating table, anesthetic device and displays
3. ***Anesthesia***
   All common anesthesia methods such as local, epidural, spinal, and general anesthesia can be used in UBE surgery. General anesthesia or local anesthesia and sedation with midazolam and dexmedetomidine (Precedex) are usually applied. In the case of epidural anesthesia, sedation is performed with midazolam or propofol to minimize the influence on the surgical procedure. Epidural anesthesia is performed on patients at a level 1 or 2 above the index level. Sometimes, if anesthesia is not possible due to the narrow interlaminar space, anesthesia is also performed at the index level. In the case of cervical and thoracic lesions, general anesthesia is applied in advance of the surgery.
4. ***Position***
   The patient is positioned prone on a radiolucent surgical table comfortably, commonly with Wilson frame, placed on a standard operating room table (Fig. 2.4). Antiseptic skin preparation is completed using betadine and alcohol. Considering that UBE surgery uses lots of irrigating saline during surgery, an endospine pack with a fluid-collecting bag should be applied. If a ready-made UBE specialized

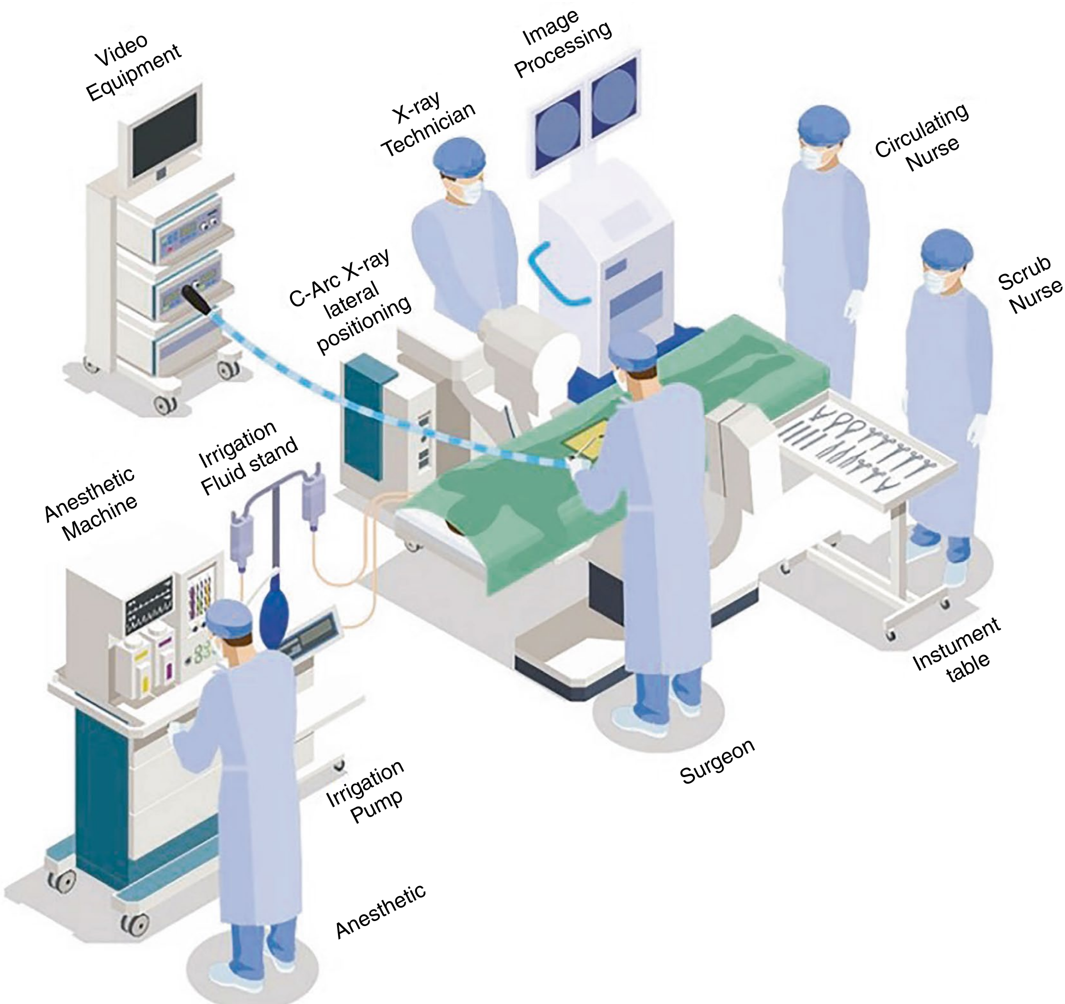

Fig. 2.2 Graphical illustration of the basic operating room setting

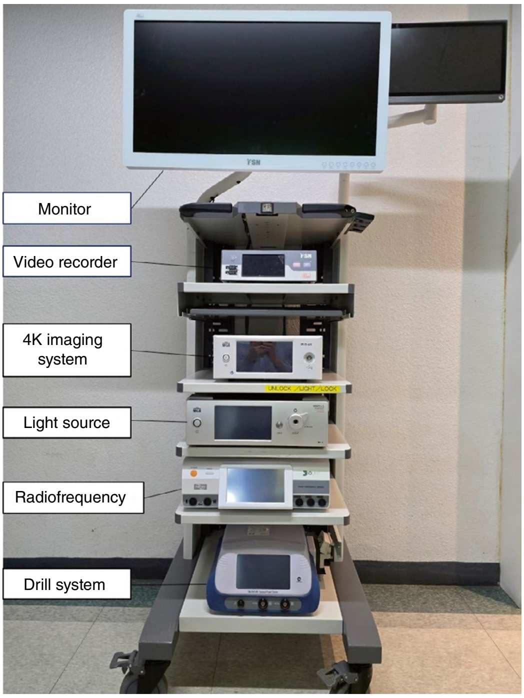

Fig. 2.3 Endoscopy tower system

Fig. 2.4 Patient positioning and operating room setup

surgical drape is not available, try to make a hump around the operative site and attach a sterilized vinyl bag to collect the used saline.

2.8 Instrument Settings

1. ***Endoscopy tower system***
   In UBE surgery, the same endoscopy tower system used in shoulder arthroscopy is employed. The tower system typically consists of a monitor, video recorder, 4K imaging system, light source, radiofrequency equipment, and drill system. The tower system is situated facing the surgeon, providing a monitor view of the surgical field (Fig. 2.3).
2. ***Endoscope***
   The 0° endoscope is commonly used because it blocks any vision distortion that could be caused by an angled lens. Additionally, depending on the operator's preference, a 30° scope is also used because it can provide wider side view with a minimal movement of the endoscope such in a case of ventral decompression at the thoracic spine (Fig. 2.5). Furthermore, during decompression of lumbar canal stenosis, using a 30° scope instead of a 0° scope is believed to reduce the scope's inclination, potentially achieving successful decompression with less amount of bone work [13].
3. ***Drill***
   A standard endoscopic drill burr is effective for controlling the water pressure in the working space and for bone dust drainage (Fig. 2.6). Various types and sizes of drill tips can be used depending on the surgeon's preference. The ball type is frequently employed, while cutting burrs and diamond burrs are common choices (Fig. 2.7). A drill sheath can also be utilized as needed. However, it is advisable to use a profile that can reduce turbulence within the surgical field.
4. ***Radiofrequency probe***
   RF plasma is a very effective energy source for coagulation and ablation in fluid situations. The heat generated by RF firing can vary depending upon the irrigation flow rate, the RF power level, and firing time. Eighty degrees Celsius heat may cause permanent tissue damage [14]. Even low temperature heat that is applied continuously can cause moderate-temperature burns. Frequent, short-term, and brief use of the RF wand is recommended rather than one prolonged application. The following are the energy parameters recommended for RF application (based on the Arthrocare® RF device) (Table 2.2).

A RF probe is composed of 90°, 30°, and ball type (Fig. 2.8). The 30° probe is useful for

Fig. 2.5 Endoscope sheath, 0° and 30° endoscope (left, from the top), tip of 0° and 30° endoscope (right)

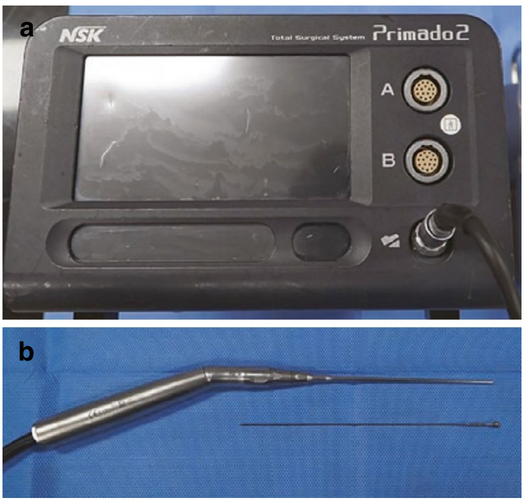

Fig. 2.6 (**a**) Waterproof endoscopic diamond drill setup box; (**b**) handpiece and diamond drill

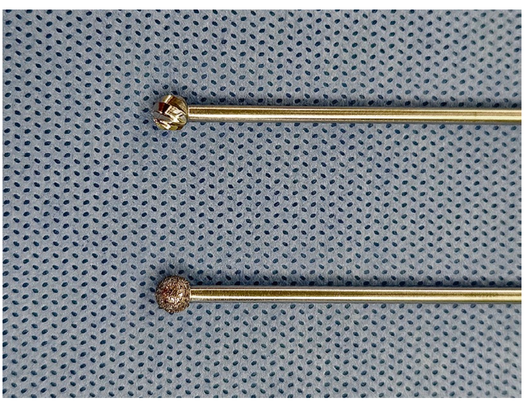

Fig. 2.7 Cutting burr and diamond burr (from the top)

Table 2.2 The energy parameters recommended for radiofrequency application

	The energy parameter (based on the Arthrocare RF device)	
	Ablation	Coagulation
The area above the bone	7	2
The epidural space	3	1
Near the dura mater	X	1

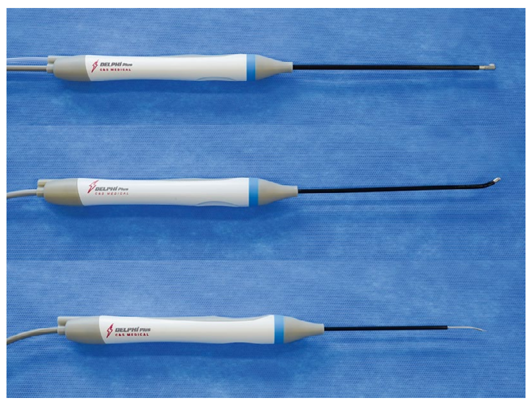

Fig. 2.8 90° RF probe, 30° RF probe, ball-type RF probe (from the top)

disk ablation. The ball-type probe is useful when cauterizing small blood vessels around the disk and blood vessels mixed around adipose tissue.

5. ***Kerrison rongeurs and pituitary forceps***
   The Kerrison rongeur and pituitary forceps are commonly used instruments in general spine surgery and can be utilized from open surgery settings as they are (Fig. 2.9). Rotating-type Kerrison rongeurs are particularly useful for grasping and removing structures in awkward positions while keeping the hand comfortably positioned (Fig. 2.10). Curved Kerrison rongeurs, also known as foraminal punches, are beneficial for decompressing the contralateral foramen when addressing central stenosis (Fig. 2.11).
6. ***Chisels***
   Chisels are effective tools for swiftly removing bone structures to expose the desired target. Care should be taken to securely position the chisel with approximately double the thickness and to carve away like sculpting, ensuring not to inadvertently strike soft tissues, thus minimizing the risk of dural injury. These endoscopy-specific chisels are equipped with depth-indicating dots for bone cutting. They are also available in various curved shapes, allowing for precise chiseling as needed (Fig. 2.12).
7. ***Straight and angled curettes***
   In open surgery, curettes are commonly used to scrape and remove cartilaginous endplates in the disc space. However, in biportal endoscopic surgery, they are useful for dissecting the ligamentum flavum (Fig. 2.13). By sparing the deep layer of the ligamentum flavum and dissecting and removing the superficial layer with a curette, it is recommended to reduce the risk of dural tear more effectively with en bloc fashion than with piecemeal resection using Kerrison rongeurs. After dis-

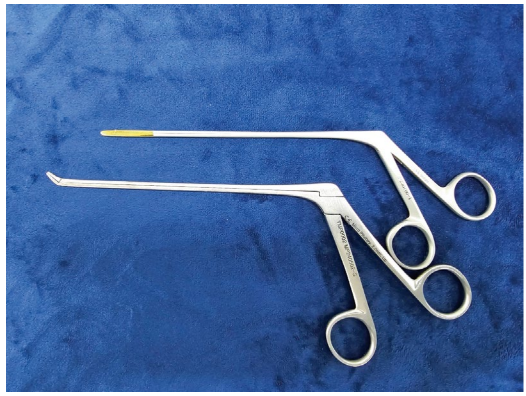

Fig. 2.9 Pituitary forceps

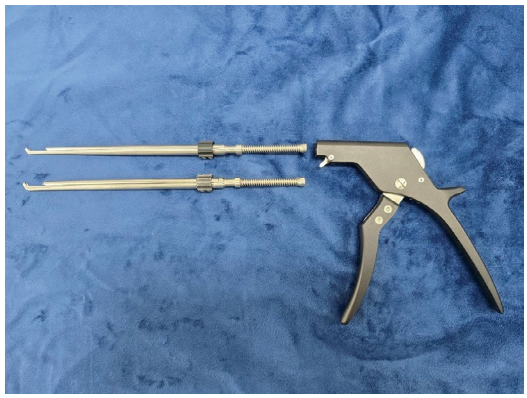

Fig. 2.10 Rotating-type Kerrison rongeurs

Fig. 2.11 Curved Kerrison rongeurs

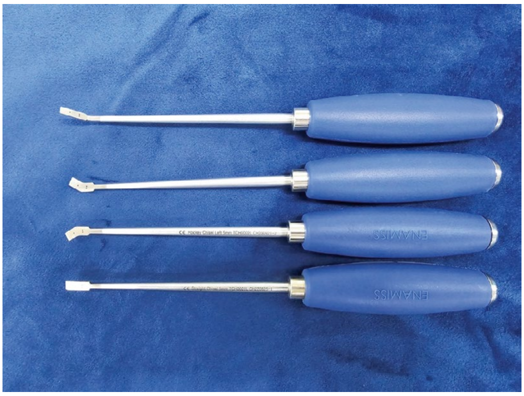

Fig. 2.12 Pedicle chisel, right hockey stick chisel, left hockey stick chisel, straight chisel (from the top)

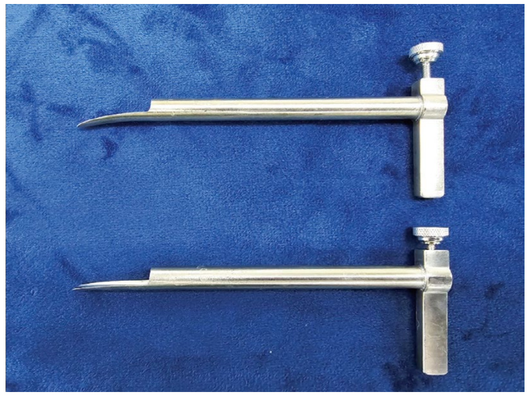

Fig. 2.14 Endoscope retractors

Fig. 2.13 Straight and angled curettes

Fig. 2.15 Working sheath retractor attached to the serial dilators

secting along the edge of the ligamentum flavum with a curette, a pituitary forceps is then used to remove it totally.

8. ***Endoscope retractors***
   This endoscope retractor was developed inspired by full endoscopy. It is used by applying it additionally over the outside of the scope sheath (Fig. 2.14). It is the only instrument that can be used through the scope portal. This allows for retraction of the neural component without the need for an assistant.
9. ***Working sheath retractors and serial dilators***
   After muscle dissection at the working portal, the space is secured using serial dilators, and then a working sheath is attached to the serial dilators, allowing insertion without damage to surrounding muscles (Fig. 2.15). The working sheath can be acted by connecting on both sides to retract muscles from the inside after insertion. The semicircular type enhances the maneuverability of surgical instruments, making it convenient to use (Fig. 2.16).
10. ***Muscle detacher***
    This device plays a role in securing the working space by detaching muscles from the bony structures near the lesion of interest, following fascia incision at the beginning of surgery (Fig. 2.17). During work in the interlaminar space, caution must be taken not to excessively damage the ligamentum flavum, to avoid direct exposure of neural structures.

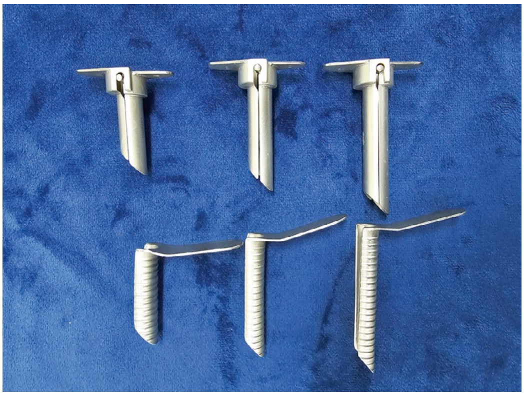

Fig. 2.16 Working sheath retractors

Fig. 2.17 Muscle detacher

11. ***Root retractor and nerve freer***
    It is possible to use the tools originally used in open surgery. However, these instruments have been modified for endoscopic use, with slightly increased length and adjustable size (Figs. 2.18 and 2.19). In cases where direct insertion of the root retractor is challenging due to spatial constraints, the retractor can be flipped 180° so that it faces the lateral side of the disc and then rotated back 180° to retract the nerve root.
12. ***Annulotomy knife***
    This instrument, derived from the freer septum knife, is currently being used in endoscopic surgery. It is also referred to as an *Indian knife*. It is employed to create an opening in the annulus by applying the pushing force with this blunt knife against the disc. While discectomy can be begun using a blade, there is a risk of inadvertently puncturing the dura during approach. In contrast, this instrument has a dull end, minimizing the risk of harming the dura (Fig. 2.20).

Fig. 2.18 Root retractor

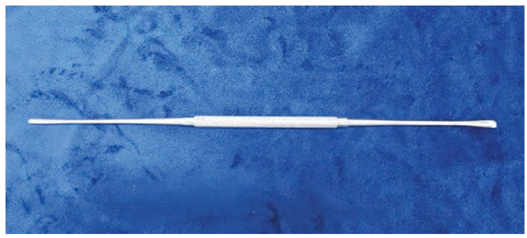

Fig. 2.19 Nerve freer

Fig. 2.20 Annulotomy knife

2.9 UBE Should Be Performed with a Complete Understanding of the Eight Basic Concepts

The following insights, authored by pioneer Dr. Sang-Kyu Son, outline foundational concepts essential for starting UBE. Acquainting yourself with these concepts beforehand can minimize trial and error. We recommend reading these before embarking on your UBE journey.

UBE has eight basic concepts as follows (Fig. 2.21):

1. ***Unilateral biportal endoscopy***
   The very first use of the terminology "biportal" in spinal endoscopy was in the "bilateral biportal approach" in the late 1990s, and it referred to the surgical approach to the transforaminal area in percutaneous endoscopic lumbar discectomy (PELD) [15]. UBE applies the knee arthroscopy surgical concept to the spine, and that is why UBE is simply explained as a biportal system. UBE is spinal endoscopy where two portals are made in the same (unilateral) side of the spine. One is used as the endoscopic portal and the other is used as the working portal. When this new spinal endoscopy technique was started in early 2000, the author intentionally called "unilateral biportal endoscopy (UBE)" to differentiate it from the "bilateral biportal approach" in PELD. The benefit of the unilateral approach is that the surgeon uses the same surgical route as in conventional surgery, and the benefit of biportal endoscopy is that the endoscope of the endoscopic portal and the instruments of the working portal move independently. The functionality of the independent movement of the devices in each portal enables the surgeons to eliminate visual and motion limitations.
2. ***Fluid-medium surgery***
   UBE uses irrigating saline, whereas conventional surgery does not use any medium. While performing UBE, the working space becomes filled with irrigating saline, and that is why it is called fluid-medium surgery. Continuous saline output is critically important, and the controlled management of the saline output influences the hydrostatic pressure in the working space, which enables the surgeons to have a clear view of the surgical field, facilitating safer surgery. For details, please refer to the [12].
3. ***Triangulation***
   The lens of the endoscope is located in the front-most position of the endoscope. In the beginning stage of UBE surgery, it is not easy to place the instruments under endoscopic view due to many reasons. A triangular formation should be made by positioning the endoscope and surgical instruments very close together at the tips of the devices. True triangulation means locating the ends of the instruments just in front of the lens of the endoscope. If the endoscope and instruments are crossing each other in the shaft, each inter-

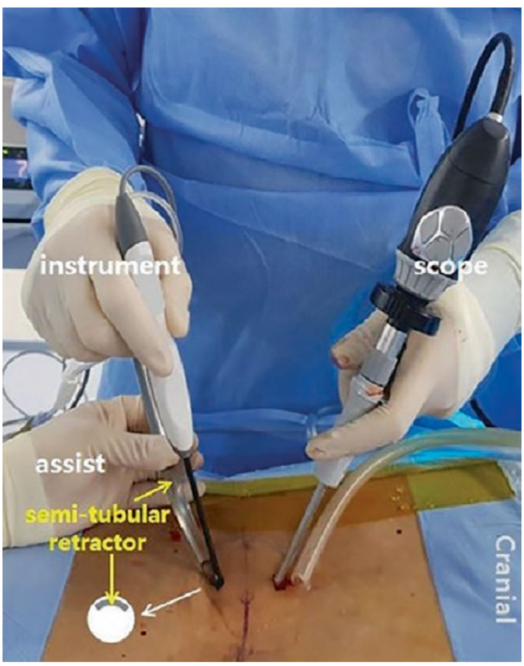

Fig. 2.21 UBE is unilateral biportal endoscopy. The non-dominant hand of the surgeon holds the endoscope, and the other hand handles the instruments. The assistant places a specially designed semi-tubular retractor in the working portal. The small portion of the circle in the working portal is covered by the retractor, and the other portion is free. Then, UBE adopts a semi-tubular system

feres with the other's movement. This situation is called "early triangulation," and repositioning should be performed under C-arm radiography. Also, if the endoscope cannot be made to face the instruments at the tip, it will not be possible to find the instrument in the endoscopic view. This is called "open triangulation" and this should also be repositioned under C-arm radiography.

4. ***Semi-tubular system at the working portal***
   Although open surgery has no visual or motion limitations because the surgical field is a sufficient size, it has the disadvantage that it could be destructive surgery. To overcome this handicap, many trials of minimally invasive surgical approaches have taken place. The first and typical concept is the tubular retractor system. Microendoscopic discectomy (MED) and PELD are representative examples of the effort to overcome the destructive aspect of open surgery [16].
   UBE adopts a semi-tubular retractor (Fig. 2.16). A semi-tubular retractor is tugged into the working portal by a surgical assistant to help the surgeon place and remove instruments while maintaining the smooth outflow of saline and tugging away neural structure or soft tissue in the working space for a clear view. A small portion of the circle in the working portal is covered by the retractor, and it functions just like in the tubular retractor system. The other portion of the working space is exposed without any covering by a rigid tubular-like device. Thus, the free movement of instruments is secured as in open surgery. This is called a semi-tubular retractor system. The semi-tubular retractor has additional benefits from the unique features of the design. It has a groove in the shaft, so it guarantees better output flow, enables a working space by retracting the upper small muscle of the multifidus, performs the role of an instrument guide, and retracts nerve root if needed.
5. ***Generally, one-hand surgery***
   In conventional surgery, especially while doing some sensitive surgical actions in a risky anatomical space, the nondominant hand supports the main acting hand for safe performance. But, in UBE, the nondominant hand holds the endoscope, and the dominant hand operates the surgical instruments. Accordingly, the dominant hand should function without any support from the nondominant hand. That is why this is called one-hand surgery. No matter what, safe surgery is most important. To compensate for the lack of a backup hand, we need instrument modifications such as blunt-edge instruments and varied-angled freer. The corresponding changes should be made in surgical skills like the splitting and elevating technique while eliminating the ligament flavum and securing enough surgical space followed by gentle motions for safe surgery at the sensitive cord level.
6. ***Lens inside the body***
   The lens of the endoscope is put inside the patient's body, so it is easy to determine the pathologic region directly. This is not possible in microscopic surgery. The contralateral side of the spinal canal, foraminal area, the L5-S1 extraforaminal area and the ventral side of the thoracic dura are not exceptions. Irrigating saline is continually inflowed through the tip of the sheath of the endoscope, and the flow pressure somewhat controls hemorrhage and washes away the hematoma for a clear surgical field.
7. ***A movable, not fixed lens***
   Because the nondominant hand holds the endoscope, the surgeon might experience a trembling endoscopic view. This can be prevented somewhat by placing the arm close to the body. In surgery performed under triangulation formation, the endoscope and the instruments work independently very adjacent to each other, and the wide vision is an advantage, but there is a high risk of causing damage to the endoscope lens by speeding drill burrs and energy from the RF wand. To prevent this, a consistent distance between the endoscope and the instruments should be maintained. Keep in mind that a small movement of the tip of the endoscope results in very different surgical vision.

8. ***Instrument and endoscope to be handled with pivot movement***
   In open surgery, the surgical field is open, so when moving the instruments, horizontal movement should be considered. But in UBE, pivot movements should be made, using the two portals as the central pivot point. For example, if you plan to move the tip of the instruments forward, then you should move the tip of the other instruments, which are outside of the patient's body, backward. It takes some time to become accustomed to this during the learning curve period.

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3 Anesthesia in Unilateral Biportal Endoscopic Spine Surgery

Seung Youn Kang

3.1 Introduction

Spine surgery, routinely performed in both elective and emergency settings, has undergone substantial advancements in surgical and anesthetic techniques in recent decades. These innovations have significantly enhanced patient safety and improved postoperative outcomes. Modern anesthetic management emphasizes not only conventional perioperative assessments but also strategies aimed at promoting rapid recovery and minimizing postoperative complications.

While general anesthesia has traditionally been the anesthetic of choice for spine procedures due to its ability to maintain patient immobility and secure the airway—particularly during complex surgeries lasting over 4 h—it is not without associated risks. These risks are particularly pertinent for vulnerable populations, including elderly patients and individuals with preexisting cardiopulmonary conditions, thereby underscoring the necessity for alternative anesthetic options.

Regional anesthesia, specifically epidural anesthesia, presents a valuable alternative for lumbar spine surgeries, offering better hemodynamic stability, reduced intraoperative blood loss, and a lower incidence of postoperative complications. Furthermore, the implementation of enhanced recovery after surgery (ERAS) protocols has profoundly transformed perioperative care in spinal surgery. By fostering a multidisciplinary approach, ERAS enhances patient management, incorporating elements such as preoperative counseling, nutritional optimization, advanced anesthesia techniques, and proactive pain control.

In conclusion, the evolving landscape of anesthetic management in spine surgery underscores the critical importance of selecting an appropriate anesthetic modality to optimize patient outcomes and ensure safety throughout the surgical continuum.

3.2 General Anesthesia in Spine Surgery

General anesthesia (GA) is the preferred anesthetic technique for spinal surgeries, offering controlled unconsciousness, patient immobility, and secure airway management, which are critical for procedures involving prone positioning [1–5]. GA ensures optimal surgical conditions through effective muscle relaxation and hemodynamic control, and its reliability and familiarity make it a favored choice among anesthesiologists [6–10]. The flexibility of GA to extend the duration of surgery as required is especially

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Table 3.1 Advantage of general anesthesia

Advantages of GA
Secure airway
Controlled loss of consciousness
Ability to extend anesthetic duration
Ability to ensure patient immobility
Improved surgical exposure with muscle relaxants

advantageous in patients with respiratory challenges or obesity, ensuring secure airway management during prolonged procedures [11]. Despite inherent risks, particularly in elderly or cardiopulmonary-compromised patients [12–19], GA remains the standard method for major spinal surgeries due to its provision of a secure and controlled surgical environment (Table 3.1).

3.3 Regional Anesthesia in Lower Thoracic to Lumbar Spine Surgery

Regional anesthesia (RA) encompasses not only spinal and epidural anesthesia but also includes concepts such as peripheral nerve blocks, including the erector spinae plane block (ESPB) and others in a manner that provides supplementation when needed. Regional anesthesia (RA), particularly epidural anesthesia (EA) and spinal anesthesia (SA), is commonly utilized in lumbar spine surgery. While general anesthesia is often preferred in spinal surgery due to its familiarity, rapid implementation, and convenience, RA is deemed safe and effective for short lumbar surgeries, suggesting potential for wider application in this field [20].

The benefits of RA over GA in lumbar spine surgery are numerous, including improved perioperative hemodynamic stability, decreased mortality rates, reduced blood loss, lower risks of thrombosis, pulmonary embolism, myocardial infarction, and renal failure, as well as a decreased likelihood of cognitive dysfunction [21–25]. These advantages are thought to stem from mechanisms like altered coagulation, increased blood flow, improved postoperative respiratory function, and minimized surgical stress responses [26, 27].

Table 3.2 Advantages and contraindications of regional anesthesia

Advantages of RA	
Reduced mortality	
Favorable perioperative hemodynamic stability	
Reduced postoperative pain	
Reduced postoperative nausea/vomiting (PONV)	
Reduced risk of arterial and venous thrombosis	
Reduced myocardial infarction, dysrhythmia	
Reduced position-related complications	
Reduced renal failure	
Reduced incidence of cognitive dysfunction	
Reduced intraoperative blood loss	
Reduced postoperative pulmonary complications	
Shorter length of hospital stay	
Absolute contraindications	*Relative contraindications*
Patient refusal	Coagulopathy
Infection at the site of injection	Sepsis
Uncorrected hypovolemia	Fixed cardiac output state
Allergy	Indeterminate neurological disease
Increased intracranial pressure	

Furthermore, RA allows patients to comfortably assume the prone position independently, potentially reducing position-related injuries like pressure necrosis, blindness, and pressure sores [4, 5, 28]. While there are contraindications for regional anesthesia, significant evidence suggests that it is associated with reduced mortality and postoperative complications, making regional anesthesia a valuable option in the context of lumbar spine surgery (Table 3.2). Although regional anesthesia has demonstrated various intraoperative and postoperative advantages, the overall comparative research remains inconclusive due to variations in study methodologies [29–31].

To begin with, it is essential to examine the relevant anatomy. The spinal cord, a critical component of the central nervous system, is enveloped by three layers of membranes known as the meninges. From the outermost layer inward, these include the dura mater, the arachnoid mater, and finally, the pia mater, which provides protective coverage for the spinal cord.

Anesthesia is typically performed via a posterior approach. Upon penetrating the ligamentum flavum, the first space encountered is the epidural space. This epidural space extends posteriorly, anteriorly, and bilaterally.

Continuing inward, one encounters the dura mater, which translates from Latin as "tough mother." Although it exhibits less resistance compared to the ligamentum flavum, a distinct tactile sensation is perceived upon penetration. Beyond the dura mater lies the subdural space, which is located both posteriorly and anteriorly. Further advancement through the arachnoid mater leads to the subarachnoid space, where the spinal nerves are suspended in cerebrospinal fluid (CSF) and encased by the pia mater. This space resembles a water-filled tube.

In summary, from the outermost to the innermost layers, the sequence consists of the epidural, subdural, and subarachnoid spaces. Theoretically, it is possible to administer anesthesia within all three of these anatomical compartments (Fig. 3.1a and b).

3.3.1 Epidural Anesthesia

Epidural anesthesia is performed by puncturing the ligamentum flavum to administer local anesthetics into the epidural space, located between the dura mater and the ligamentum flavum. It is crucial to recognize that the epidural space, accessed through a posterior approach, extends not only posteriorly but also laterally and anteriorly. This configuration enables the anesthetic agent to diffuse throughout the space, effectively reaching the bilateral spine nerves including dorsal root ganglia to anesthetize the dermatomes at each level or diffusing centrally inward to the spinal nerves. Consequently, the onset time for epidural anesthesia typically ranges from 15 to 20 min. During the diffusion process, the anesthetic may extravasate into adjacent spaces such as blood vessels or adipose tissue, necessitating the use of larger volumes of anesthetic. In many cases, epidural anesthesia may require the utilization of the maximum allowable daily dosage. In comparison with spinal anesthesia, the sensory, motor, and sympathetic nerve block effects of epidural anesthesia are generally less profound, which translates to fewer fluctuations in blood pressure. Furthermore, the extent of motor blockade is relatively minimal, which facilitates the performance of postoperative neurologic examinations (Table 3.3).

In the context of spine surgery, epidural anesthesia must provide coverage not only at the level of the surgical site but also extend to the

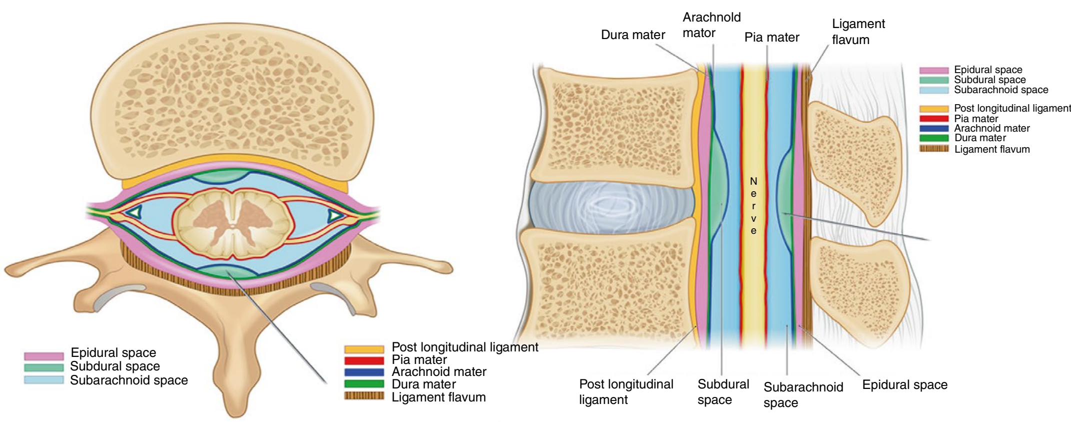

Fig. 3.1 Epidural-inadvertent subdural-subarachnoid space (from outside to inside). (**a**) The axial view: the subdural and subarachnoid spaces exist within the dural sleeve, while the epidural space exists beyond exiting roots. (**b**) The sagittal view: the epidural and subdural spaces are two distinct layers, whereas the subarachnoid space exhibits a single tubular morphology akin to a water tube. (From Kang SY, Cho HS, Yi J, et al. Epidural, inadvertent subdural, and combined epidural-subdural anesthesia in lumbar spine surgery: A retrospective analysis. J Pers Med. 2024;14 (5):486)

Table 3.3 Comparison between epidural and subarachnoid (spinal) anesthesia

	Epidural anesthesia	Spinal (subarachnoid) anesthesia
Onset of anesthesia	15–20 mins	< 5 mins
Local anesthetic dose	Larger dose (> 10 mL of 0.5% bupivacaine)	Smaller dose (<3 mL of 0.5% bupivacaine)
Risk of local anesthetic toxicity	Considerable	Negligible
Duration of anesthesia	160–220 mins	90–150 mins
Intensity of anesthesia	Less dense	More dense
Hemodynamic alterations	Less pronounced (slow)	Pronounced (rapid)
Motor block	Less frequent	Almost always
Anesthetic administration level in the spine	At any level of the vertebral column	Below L1/L2, where the spinal cord ends
Incidence of patchy block	Frequent	Very low
Intraoperative redosing	Possible, via catheter	Generally, a single shot

associated incision dermatome, necessitating adequate anesthesia to encompass the mid to lower thoracic levels. Traditional methods of predicting anesthesia levels in blind epidural techniques using patient height and volume have proven unreliable. A study by Kang et al. found no significant correlation between contrast-enhanced anesthetic epidural injection volume, patient height, radiographic spread, and analgesic outcomes [32]. This finding aligns with prior research demonstrating variability in anesthetized regions following epidural blocks [33]. Furthermore, traditional blind techniques relying on tactile cues may increase the risk of total spinal anesthesia via the midline gap of the ligamentum flavum [34]. An effective alternative is fluoroscopy-guided epidural anesthesia using contrast media, which offers accurate predictions of distribution and enhances procedural time efficiency [35, 36].

The stability and duration of epidural anesthesia have been questioned in the context of endoscopic spine surgery, where the constant flow of irrigation fluid could potentially wash away the anesthetic agent from the epidural space. Kang SY et al. reported that, contrary to this concern and the findings of previous studies [37, 38], epidural anesthesia achieved with a single injection of an anesthetic agent provided sufficient surgical anesthesia for up to 3–4 h of operation time [36]. While the dose of the local anesthetic (dose = concentration × volume) is the most important determining factor for anesthetic duration, its efficacy can be enhanced by the co-infusion of dexmedetomidine, which may improve the quality of anesthesia and prolong its duration [39, 40].

3.3.2 Subarachnoid (Spinal) Anesthesia

Spinal anesthesia is performed by administering anesthetic agents into the subarachnoid space, where the spinal nerves are suspended in cerebrospinal fluid. This technique produces a rapid onset of anesthesia and has significant effects on sensory and motor nerve blockade. Furthermore, it results in substantial sympathetic nerve blockade, especially in cases of high-level block above T4. Such sympathetic blockade may lead to notable drops in blood pressure. Furthermore, the pronounced motor blockade can complicate postoperative neurologic examinations. Additionally, spinal anesthesia typically has a shorter duration of action compared to epidural anesthesia (Table 3.3).

3.4 Fluoroscopic Guidance Epidural Anesthetic Technique

An adequate anesthesia level for lower thoracic to lumbar spinal surgery is considered at T6–T10 [20, 32]. The fluoroscopic epidural anesthesia technique for patients undergoing spinal surgery,

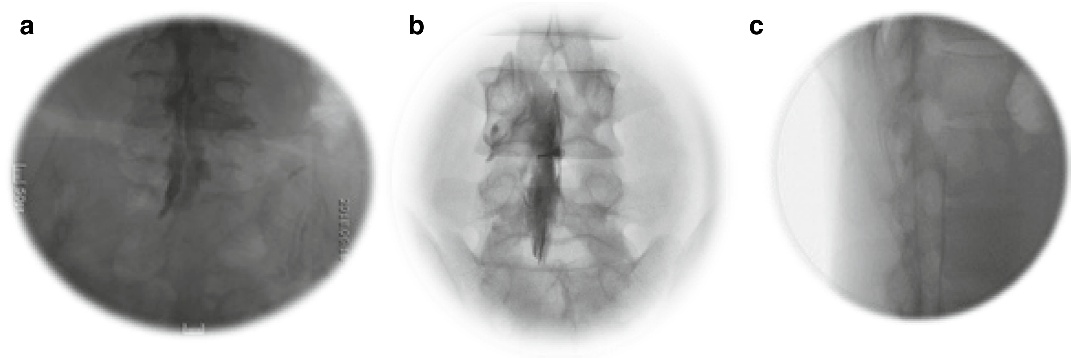

Fig. 3.2 Epidural image. (**a, b**) AP view: The contrast media outlines the exiting nerve roots in a "Christmas tree" pattern. The presence of vacuolation linked to epidural fat is a distinct feature. Adhesions, pathology, and anatomical variances may impact the variety of observed epidural contrast patterns. (**c**) Lateral view: The outermost anterior and posterior boundaries of the spinal canal, delineating the epidural space

as described in the literature by Kang SY et al. is presented below [32, 35].

Upon arrival in the operating room, the patients were placed in the prone position on a Wilson frame. Their faces rested in a hollowed-out rectangular face protection cushion, and they received 3 L of oxygen via a nasal cannula. Local anesthetic was injected into the skin, and a 20-gauge Tuohy needle was introduced into the nearest interlaminar epidural space cranial to the operative level, where the ligament flavum appears thick and taut in preoperative MRI. After identifying the epidural space using the loss-of-resistance technique and confirming with AP and lateral fluoroscopy using contrast media (Fig. 3.2a, b, and c), a single injection of a concoction of 7.5–15 mL of 0.75% ropivacaine with 1:200,000 epinephrine diluted in 2.5–5 mL of a radiocontrast dye was administered. The dye reached the lower to mid-thoracic epidural space for adequate coverage of the surgical field and incisional dermatome. In cases of significant epidural adhesions or severe stenosis, additional epidural injections were administered above or below the operative level to ensure proper coverage. If the epidural needle was positioned within the subdural (Fig. 3.3a and b) or subarachnoid space (Fig. 3.4), it was removed, and epidural anesthesia was attempted at a different level. If a patient was deemed stable and comfortable, a capnogram monitor was placed on their cheek or under their nose to monitor their respiratory status. The hollowed-out face cushion created a small pseudo-sealed chamber for the capnogram to obtain readings from. MAC targeted at deep sedation was initiated using a loading dose of 1 mcg/kg of dexmedetomidine for 10 min, followed by a maintenance dose of 0.6–0.7 mcg/kg/h of dexmedetomidine. Additionally, 20 mcg/mL of remifentanil was infused at a rate of 5–7 mL/h, along with 1–2 mg of midazolam based on the patient's age, sex, and adjusted body weight. Hourly administration of an additional 1 mg dose of midazolam was continued. Further dosing of these medications was adjusted based on regular assessment of the patient's respiratory status and degree of sedation.

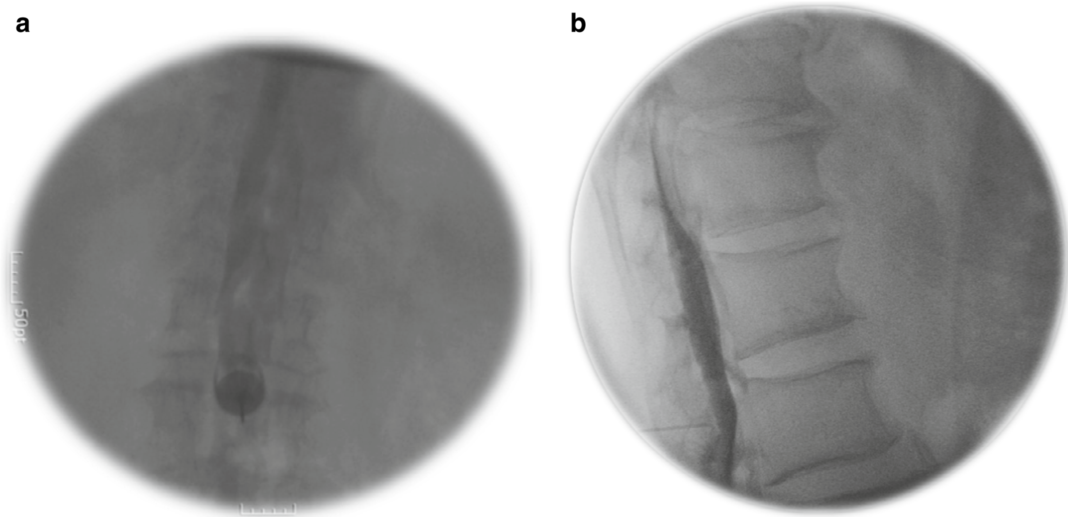

Fig. 3.3 Subdural image. (**a**) AP view: a narrow column of contrast medium is confined to the central portion of the spinal canal and does not extend, outlining the exiting spinal nerve roots laterally. (**b**) Lateral view: the absence of CSF dilution and drainage; a longer duration persists, often remaining confined to the dorsal canal with a flat dorsal margin (dura mater) and an anterior bulging contrast (arachnoid mater) due to a smaller potential ventral subdural space

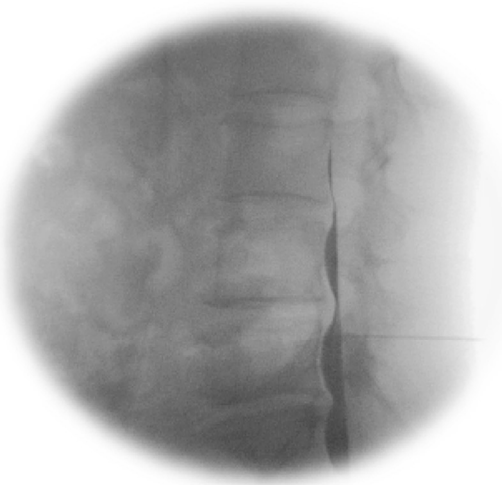

Fig. 3.4 Subarachnoid image in lateral view: a single-layer image shows a pattern of hyperbaric contrast medium in the most ventrally dependent region featuring ventral undulations attributable to the arachnoid mater when in the prone position. There is a line of lucency between the contrast spread and the posterior vertebral body, suggestive of the area pertaining to the anterior epidural-subdural space

3.5 Enhanced Recovery After Surgery (ERAS) for Spine Surgery

Enhanced recovery after surgery (ERAS) programs, integrated across a range of surgical disciplines, prioritize evidence-based perioperative strategies to mitigate surgical stress response, lower postoperative complications, optimize functional recuperation, and enhance patient-reported outcomes by implementing a comprehensive, multidisciplinary care model involving preoperative counseling, nutritional support, advanced anesthesia modalities, and proactive pain management interventions [41]. Despite the lack of official guidelines for spine surgery, recent cohort studies suggest promising results [42–44]. Elements like preoperative analgesics and minimally invasive techniques have shown significant benefits, enhancing early recovery and cost-effec-

Table 3.4 Guidelines of enhanced recovery after surgery (ERAS) in spine surgery. (Adapted from P. Khanna et al. Anesthetic considerations in spine surgery. (Journal of Clin Orthop Trauma. 2020;11:742–748))

Preoperative	Intraoperative	Postoperative	Overarching principles
1. Patient education and counseling	1. Minimally invasive techniques with small incision	1. Early mobilization	1. Multidisciplinary
2. Risk assessment screening and intervention	2. Total intravenous anesthesia (TIVA) or regional anesthesia when possible	2. Prompt nutrition	2. Communication
3. Carbohydrate loading	3. Normovolemia and normothermia maintenance	3. Cessation of intravenous fluids	3. Iterative feedback process with compliance measures
4. Shortened fasting 6 ~ 8 h preoperatively	4. Opioid-limited or opioid-free analgesia	4. Postoperative monitoring and follow-up with enhanced recovery after surgery team	4. Evidence-based evaluation of all elements
5. Analgesia regimen with acetaminophen and gabapentin		5. Nonopioid pain management	5. Early reintroduction to preoperative functions and activities

tiveness while offering potential improvements in patient outcomes (Table 3.4) [45].

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4 Unilateral Biportal Endoscopic Spine Surgery in the Ambulatory Surgical Center with an Enhanced Recovery After Surgery Pathway

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4.1 Introduction

Ambulatory surgical centers (ASCs) are specialized healthcare facilities that provide surgical procedures that do not require an inpatient hospitalization, serving as an alternative to hospital-based surgery. They offer an alternative surgical care setting aimed at increasing the efficiency of medical resources to reduce healthcare costs with similar clinical outcomes and complication rates as hospital-based surgeries. Moreover, there are several advantages including a lower rate of cancellations, reductions in waiting times with increased accessibility, and the decreased risk of nosocomial infections [1]. Existing studies related to spinal surgery in ASCs have focused on ACDF, decompressive laminectomy/laminotomy with or without lumbar discectomy, full-endoscopic transforaminal lumbar discectomy, and lumbar fusion surgeries [2–5]. The studies have shown that these surgeries can be performed safely, effectively, and with less cost as compared to the hospital setting [6–8]. The advancement of minimally invasive surgical techniques has allowed patients to undergo spine surgery at ASCs through the minimal surgical footprint that limits tissue damage and blood loss, thereby reducing postoperative pain and time for recovery [9].

Enhanced recovery after surgery (ERAS) is a multidisciplinary approach to surgical care that aims to improve clinical outcomes and reduce medical costs. ERAS was developed 20 years ago in Western Europe for abdominal surgery and has shown impressive proliferation across various surgical subspecialties [10]. Notably, since it was first published by Wainwright et al. in 2016, it has been studied extensively in field of major spine surgery [11]. While showing no differences in complication, readmission, and reoperation rates compared to traditional surgical care, ERAS has emerged as an attractive option in the field of spine surgery by reducing the length of hospital stay and medical costs [12].

Unilateral biportal endoscopy (UBE) is an ultra-minimally invasive technique that can lead to less postoperative pain, early functional recovery, reduced postoperative narcotic usage, and

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