ENDOSCOPY AND FETOSCOPY TECHNIQUES FOR THE BRAIN AND NEUROAXIS

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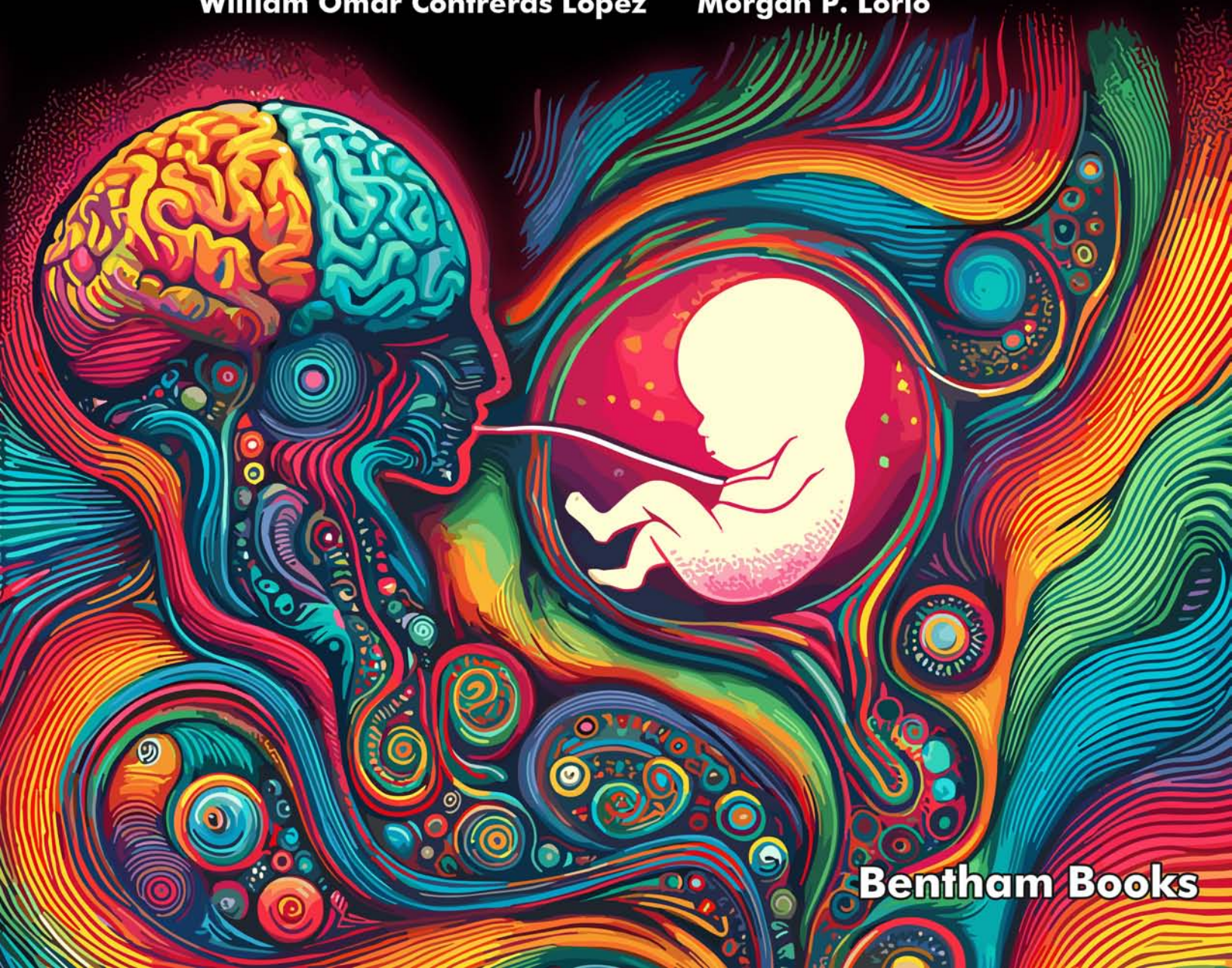

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Neuroendoscopy and Interventional Pain Medicine (*Volume 2*)

Endoscopy and Fetoscopy Techniques for the Brain and Neuroaxis

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(Volume 2)

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ENDORSEMENTS

SICCMI (Sociedad Interamericana Cirurgia de Columna Minimamente Invasiva)

Founded in 2006, SICCMI aims to advance and mainstream minimally invasive spine surgery (MIS), aligning with the objectives of Neuroendoscopy & Interventional Pain Medicine. Our members have worked to implement MIS throughout South America, the Caribbean, Central America, and North America. Many of our key opinion leaders perform endoscopic surgery at the highest level and have contributed to this comprehensive multi-volume text. Four of the editors hold leadership positions within SICCMI. The table of contents is extensive, covering the cervical and lumbar spine and advanced technological applications. This book will serve as the core curriculum and course material for endoscopic spine surgery within SICCMI. It is my pleasure to endorse it on behalf of our society.

Alvaro Dowling

Past President of SICCMI

ISASS

The origins of the International Society for the Advancement of Spine Surgery (ISASS), formerly known as The Spine Arthroplasty Society, can be traced back to its focus on motion preservation as an alternative approach to fusion. Over time, ISASS has remained dedicated to its overarching mission of serving as a worldwide hub for scientific exploration and education, centered around the needs of surgeons.

ISASS was established with the primary goal of creating an impartial platform where experts could openly discuss and tackle various aspects of both fundamental and clinical research related to motion preservation, stabilization, cutting-edge technologies, minimally invasive procedures, biologics, and other crucial subjects aimed at restoring and enhancing spinal motion and function. The society boasts a diverse and thriving global membership consisting of orthopedic and neurosurgery spine surgeons as well as scientists.

ISASS stands committed to pushing the boundaries of spinal techniques and procedures, including groundbreaking approaches like endoscopic spine surgery. A testament to this dedication is this text, Neuro-endoscopy, which serves as a reservoir of knowledge contributed by experts, resulting in a comprehensive and current reference text. This publication stands as a tangible example of our unwavering commitment to surgeon education and scientific advancement.

As representatives of ISASS, we take great pleasure in endorsing this all-encompassing text. It is a true reflection of our society's tireless pursuit of enhancing surgical education and promoting rigorous scientific exploration.

International Society for the Advancement of Spine – forging ahead on the path of progress.

Huilin-Lin Yang MD, PhD

ISASS Co-President, International 2023-2024

Morgan P. Lorio MD, FACS

Co-President Elect, USA 2024-2025

DR. KAI-UWE LEWANDROWSKI AMCICO ENDORSEMENT
Neuroendoscopy and Interventional Pain Medicine

Asociación Mexicana de Cirujanos de Columna A.C.

Dear Dr. Lewandrowski:

On behalf of the board of Asociación Mexicana de Cirujanos de Columna A.C (AMCICO) it´s an honor to endorse your upcoming groundbreaking text entitled *Neuroendoscopy and Interventional Pain Medicine*.

Your editors and authors highlighted the advancement and mainstreaming of minimally invasive surgery (MIS) for various topics in neurosurgery, spine surgery, and novel interventional pain management strategies involving the endoscopic technology platform. AMCICO members recently joined to discuss the implementation of MIS endoscopic surgery techniques in Mexico, where many of its key opinion leaders, some of whom have contributed to this outstanding text, perform endoscopic surgery at the highest level. The book content is exhaustive and comprehensive, encompassing cervical and lumbar spine topics with advanced technology applications. Moreover, your text highlights endoscopic surgery techniques of the cranium and skull base and, for the first time, describes the prenatal intra-uterine endoscopic repair of spina bifida. Neuroendoscopy and Interventional Pain Medicine will serve as AMCICO's core curriculum and course material for endoscopic surgery of the spine and neurological system. It is my pleasure to endorse it on behalf of AMCICO.

Again, we thank you for your valuable academic contribution and reiterate our disposition to assist with disseminating your outstanding text.

Sincerely

Dr. Eulalio Elizalde Martinez

President of AMCICO

Junta Directiva 2021 - 2023

SILACO (Sociedad Ibero Latinoamericana de Columna) had its beginnings in the meetings of the Scoliosis Research Society with the first Hispano-American Congress held in 1991 in Buenos Aires Argentina.

Since then, it has morphed into an organization that promotes the study of treatments and prevention of spinal conditions by bringing together spine care professionals from all subspecialties.

The scientific activities of our biannual Ibero-Latin American Congress are focused on the promotion of surgeon education to the highest academic standards via international relationships between members from the Americas, Spain and Portugal.

Neuroendoscopy and interventional Pain Management resembles such a collaborative effort where authors worldwide have come together to update the reader on the latest endoscopic spinal surgery techniques.

SILACO has incorporated Neuroendoscopy and interventional Pain Management into its core curriculum and plans on using it as course material for its continuing education courses.

It is my pleasure to endorse it on behalf of SILACO.

Dr. Jaime Moyano
President of SILACO

Editor SEOT Magazine
Ecuadorian Society of Orthopedics and Traumatology – SEOT

SOMEEC - Sociedad Mexicana de Endoscopia de Columna

SOMEEC - Sociedad Mexicana de Endoscopia de Columna – is Mexico's prime organization uniting spine surgeons with diverse training backgrounds who have a fundamental interest in endoscopic surgery. SOMEEC organizes annual meetings where member surgeons and international faculty update each other on their latest clinical research to promote spine care via endoscopic spinal surgery techniques. Two of the senior lead editors of Neuroendoscopy & Interventional Pain Medicine have been active international supporters of SOMEEC. I am pleased to endorse their latest three-volume reference text, Neuroendoscopy & Interventional Pain Medicine which will become an integral centerpiece of SOMEEC's continuing medical education programs.

Enrique Saldívar Farrera

President of the Sociedad Mexicana de Endoscopia de Columna

Roberto Cantu, Jr. MD

Vice President of the Sociedad Mexicana de Endoscopia de Columna

Academia Nacional de Medicina de Colombia

The Academia Nacional de Medicina de Colombia recognizes the high academic and scientific value of the comprehensive three-volume text Neuroendoscopy & Interventional Pain Medicine. developed by leading figures in the field—including our esteemed members of our Academy, Dr. Kai-Uwe Lewandrowski, William Omar Contreras, and Dr. Jorge Felipe Ramirez—represents a significant advancement in minimally invasive spinal surgery. It will undoubtedly serve as an essential resource for both current and future spine specialists, greatly enhancing clinical practice and patient outcomes.

Gabriel Carrasquilla MD, DrPH, MPH, MSc
President, Academia Nacional de Medicina de Colombia

Asociación Colombiana de Neurocirugía (ACNCx)

The Asociación Colombiana de Neurocirugía (ACNCx) is a non-profit, private legal entity dedicated to promoting the scientific and ethical development of neurosurgery in Colombia. Established in 1962, ACNCx is committed to advancing professional responsibility, continuous improvement, and the highest standards of patient care. ACNCx operates with a democratic structure, upholding principles of solidarity, unity, and participation. Our association is deeply involved in the education and advancement of neurosurgical practices, including innovative procedures such as prenatal endoscopic repair and endoscopic interventions for the brain, neuroaxis, and spine.

It is with great pleasure that I endorse Neuroendoscopy & Interventional Pain Medicine on behalf of ACNCx. This book highlights the groundbreaking work of Colombian authors and serves as a valuable resource for our members and the broader neurosurgical community.

Best Regards,

Alberto Dau Acosta

President

Colombian Association of Neurosurgery

International Society for Minimally Invasive Spine Surgery (ISMISS)

The International Society for Minimal Intervention in Spine Surgery (ISMISS) brings together spine surgeons from all over the world united by the constant strive for advances in minimally invasive techniques. Since its conception in 1988 on the occasion of the GIEDA-Bruxelles meeting, international coordination of educational, instructional, and scientific exchanges in minimally invasive spine surgery has been the highest priority for prior and current directories.

As the newly elected president of ISMISS, it is my great pleasure to endorse Neuroendoscopy & Interventional Pain Medicine as an extraordinary textbook of up-to-date collaborative expertise in endoscopic techniques of the spine and neuroaxis. I am convinced that it will contribute significantly to the educational process of future spine specialists.

Prof. Dr. Joachim Oertel

President ISMISS

Chinese Orthopaedic Association (COA)

Chinese Orthopaedic Association (COA), a specialty society within Chinese Medical Association, was founded in 1980. It aims to promote scientific exchange, provide orthopaedic education, and improve patient care. COA is the largest and most influential orthopaedic society in China, equivalent to AAOS in the US. Its annual meetings attract about 15,000-32000 attendees, including world-class experts, presidents of international orthopaedic societies, and leaders from national orthopaedic associations.

In line with its mission to foster global discussions and enhance surgeon education, it is my pleasure as Chairman of the COA MISS Society to endorse Neuroendoscopy & Interventional Pain Medicine. This comprehensive text, created by an international team of editors and contributors, including many from China, provides an expert update on the latest endoscopic spinal surgery techniques.

I am confident that this book will become an essential part of any reputable spine surgeon society's core curriculum and serve as valuable course material for continuing education programs. It is my honor to support Neuroendoscopy & Interventional Pain Medicine on behalf of the COA MISS Society.

Huilin Yang

Professor Huilin Yang

Chairman of COA MISS Society

Japanese Minimally Invasive Spine Surgery Society (JASMISS)

As JASMISS president I am interested in discussing advancements in surgical techniques, and collaborate on clinical trials. Through these initiatives, we continue to foster a collaborative environment that supports the continuous improvement and adoption of minimally invasive techniques in spine surgery.

This dedication to excellence is evident in Neuroendoscopy & Interventional Pain Medicine, which features numerous contributions from Asian authors showcasing their groundbreaking work. It is my pleasure to endorse Neuroendoscopy & Interventional Pain Medicine.

Professor Koichi Sairyo, MD, PhD

President of the Japanese Society of Minimally Invasive Spine Surgery (JASMISS)

Tokushima University, Japan.

Korean Research Society of Endoscopic Spine Surgery (KOSESS)

Founded in 2017, the Korean Research Society of Endoscopic Spine Surgery (KOSESS) aims to unite endoscopic spine surgeons in the Republic of Korea to advance the subspecialty through high-quality clinical research. This dedication to excellence is evident in Neuroendoscopy & Interventional Pain Medicine, which features numerous contributions from Korean authors showcasing their groundbreaking work.

It is my pleasure to endorse Neuroendoscopy & Interventional Pain Medicine on behalf of KOSESS.

Chang-il Ju M.D.,Ph.D.
President of KOSESS
Professor
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Sociedade Brasileira de Coluna (SBC)

Founded on October 12, 1994, the Brazilian Spine Society (Sociedade Brasileira de Coluna - SBC) is a scientific, non-profit organization dedicated to advancing spine surgery through basic research and clinical studies in Orthopedics and Neurosurgery. SBC is committed to the accreditation and continued education of spine surgeons in Brazil, providing its members with access to the latest scientific evidence and technological advancements in spine care. Through its monthly publication, Columna, and various online courses, including an Introduction to Endoscopy, SBC strives to keep its members at the forefront of the field.

The editors of Neuroendoscopy & Interventional Pain Medicine have created a comprehensive reference text that is essential to SBC's core curriculum for teaching endoscopy of the spine and neuroaxis. This book presents validated clinical protocols for the endoscopic treatment of cervical and lumbar spine conditions, backed by peer-reviewed articles from its contributors.

It is my pleasure to endorse Neuroendoscopy & Interventional Pain Medicine on behalf of the Brazilian Spine Society. This work will undoubtedly play a crucial role in educating the next generation of spine surgeons in Brazil.

Dr. Robert Meves

President of SBC

Sociedad Colombiana De Cirurgia Ortopedia Y Traumatología (SCCOT)

The Sociedad Colombiana de Cirugía Ortopedia y Traumatología (SCCOT) is a non-profit, autonomous, scientific organization committed to enhancing spine care and surgery for orthopaedic and neurosurgeons, as well as other healthcare professionals in Colombia. Established to foster collaboration and innovation, SCCOT unites specialists with diverse scientific interests and expertise. Our goal is to promote continuous professional development and education, ensuring our members are well-versed in the latest advancements in spinal care.

With great enthusiasm, on behalf of SCCOT, endorse the three-volume book series Neuroendoscopy & Interventional Pain Management. This text is of significant interest to SCCOT due to its advanced technological applications and comprehensive discussion of validated clinical protocols for endoscopic spinal surgery and neuroaxis interventions.

The editors of this landmark series are esteemed leaders in minimally invasive spine surgery. Their combined expertise and dedication to advancing the field are evident throughout the volumes, making this series an invaluable resource for spine surgeons and related professionals.

Neuroendoscopy & Interventional Pain Management will serve as a cornerstone for SCCOT's continuing medical education programs. The extensive table of contents covers crucial topics related to the cervical and lumbar spine, as well as the latest technological advancements. This series will undoubtedly become a vital part of our educational initiatives, equipping our members with the knowledge and tools to excel in their practice.

I am honored to endorse this significant work on behalf of SCCOT. The dedication and expertise of the editors have produced a reference text that will shape the future of spine surgery and improve patient care worldwide.

Dr. William Arbeláez Arbeláez

President Sociedad Colombiana de Cirugía Ortopedia y Traumatología (SCCOT)

Sociedad Latinoamericana de Ortopedia y Traumatologia (SLAOT) / Latin American Society of Orthopaedics and Traumatology

The Sociedad Latinoamericana de Ortopedia y Traumatologia (SLAOT) is a non-profit, autonomous, scientific organization dedicated to orthopaedic surgeons and care professionals. SLAOT unites experts with diverse scientific interests, promoting continuous professional development and education at the highest level.

Neuroendoscopy& Interventional Pain Managementis highly relevant to SLAOT due to its exemplary use of advanced technology and detailed discussion of validated clinical endoscopic spinal surgery protocols. It is my pleasure to endorse this comprehensive text on behalf of SLAOT.

Dr. Victor Naula

President of SLAOT FEDERACION

Academia Nacional de Medicina

Av. General Justo, 365 – 7º andar - Centro - Rio de Janeiro - RJ

www.anm.org.br

Rio de Janeiro, august 22, 2024

Commendation of *Neuroendoscopy & Interventional Pain Medicine*

The Academia Nacional de Medicina de Brazil remains steadfast in its commitment to advancing medical knowledge, fostering education, and upholding the highest standards in patient care. It is with great honor that we commend Dr. Kai-Uwe Lewandrowski, one of our esteemed members, and his team of leading experts for their exemplary work in producing *Neuroendoscopy & Interventional Pain Medicine*. This timely three-volume text significantly contributes to the field of minimally invasive spinal surgery and stands as an invaluable resource for current and future spine specialists, enhancing clinical practice and improving patient outcomes.

Eliete Bouskela
Presidente
Academia Nacional de Medicina

Sociedad Colombiana De Columna (SOCCOL)

The Sociedad Colombiana de Columna (SOCCOL) is a non-profit, autonomous, scientific organization dedicated to advancing spine care and surgery among orthopaedic and neurosurgeons, as well as other care professionals in Colombia. Founded to foster collaboration and innovation, SOCCOL brings together experts with diverse scientific interests and backgrounds. Our mission is to promote continuous professional development and education, ensuring our members stay at the forefront of the latest advancements in spinal care.

It is with great enthusiasm that I, on behalf of SOCCOL, endorse the three-volume book series Neuroendoscopy & Interventional Pain Management. This comprehensive text is particularly significant to SOCCOL due to its exemplary use of cutting-edge technology and detailed discussion of validated clinical endoscopic surgery protocols for the spine and neuroaxis.

The editors of this landmark series are distinguished leaders in minimally invasive spine surgery. Their collective expertise and dedication to advancing the field are evident throughout the volumes, making this series an invaluable resource for spine surgeons and affiliated professionals.

Dr. Kai-Uwe Lewandrowski, a pioneer in endoscopic spine surgery, has greatly contributed to the development and refinement of minimally invasive techniques. Drs. Jorge Ramírez, Alvaro Dowling, and William Contreras, esteemed members of the Latin American spine surgery community, have played key roles in promoting these advanced surgical practices across the region. Dr. Anthony Yeung and Dr. Xifeng Zhang, world-renowned experts, have extensively published on endoscopic spine surgery and interventional pain management, further solidifying the series' credibility. Drs. Morgan Lorio and Huilin Yang are visionary minimally invasive spine surgeons who have been instrumental in prompting policy changes at national and international levels.

Neuroendoscopy & Interventional Pain Management serves as a cornerstone for SOCCOL's continuing medical education programs. The comprehensive table of contents covers topics related to the cervical and lumbar spine, as well as advanced technological applications. This series will undoubtedly become an integral part of our educational initiatives, providing our members with the knowledge and tools necessary to excel in their practice.

I am honored to endorse this significant work on behalf of SOCCOL. The dedication and expertise of the editors have resulted in a reference text that will shape the future of spine surgery and enhance the quality of care for patients worldwide.

Dr. Connie Bedoya

President of SOCIEDAD COLOMBIANA DE COLUMNA (SOCCOL)

Sociedade Brasileira de Neurocirurgia (SBN)

The Brazilian Society of Neurosurgery (SBN), established in 1957 in Brussels and affiliated with the WFNS since 1959, has been instrumental in shaping neurosurgical education and practice in Brazil. Notably, SBN was one of the first societies in the country to require examinations for the title of master, beginning in 1972. SBN continues to encourage high standards in neurosurgery through continuous education and international collaboration and is deeply involved in shaping the curriculum and standards for neurosurgical residency programs, ensuring that both fundamental and clinical research are integral parts of neurosurgical training.

In line with our commitment to excellence, I am proud to endorse Neuroendoscopy & Interventional Pain Medicine on behalf of BSN. This textbook, crafted by global leaders in minimally invasive spine surgery, serves as an invaluable resource that will enhance the education and practice of future neurosurgical specialists.

Dr. Wuilker Knoner Campos

President,

Sociedade Brasileira de Neurocirurgia

Brazilian Society of Neurosurgery (SBN)

CONTENTS

PREFACE

Welcome to Neuroendoscopy and Interventional Pain Medicine, Vol. 2: Endoscopy and Fetoscopy Techniques for the Brain and Neuroaxis. This volume centers on sophisticated techniques and critical considerations in the rapidly developing field of advanced neuroendoscopy of the brain, anterior and posterior skull base, and spinal cord for pain, tumors, and seizures, mainly focusing on advanced intracranial, intradural, and fetoscopic procedures. It brings together the collective expertise of renowned specialists, offering an invaluable resource for clinicians and researchers dedicated to enhancing patient care through innovative surgical approaches.

The book begins with a comprehensive overview of the State-of-the-Art direct endoscopic visualization of the brain and neuroaxis, highlighting the latest advancements in imaging and visualization technologies that have revolutionized neurosurgical practices. One chapter sets the foundation for understanding the complex anatomy and pathological conditions that neuroendoscopy addresses. Trigeminal tractotomies and nucleotomies explore targeted endoscopic interventions for trigeminal neuralgia and other intractable facial pain syndromes. This chapter aims to improve outcomes for patients suffering from these debilitating conditions by providing detailed procedural insights. The endonasal endoscopic approaches to the sellar region and the anterior fossa chapter discuss minimally invasive techniques for accessing and treating pathologies in these critical regions. The authors present step-by-step methods and highlight the benefits of these approaches in reducing patient morbidity. Understanding the pathophysiology of myelomeningocele & modern surgical treatment is crucial for developing effective management strategies for this congenital condition. This chapter thoroughly examines the underlying mechanisms and contemporary fetoscopy options available to clinicians. Building on this knowledge, fetoscopy techniques for myelomeningocele outline the prenatal interventions that can be performed to mitigate the effects of myelomeningocele. The authors share cutting-edge fetoscopic techniques that hope for improved outcomes in affected fetuses. For the treatment of cancer pain, microendoscopic intradural cordotomy offers a minimally invasive option. This chapter details this approach's procedural aspects and efficacy, which targets the pain pathways within the spinal cord to provide relief for patients with intractable pain. The endoscopic anatomy of the transcallosal hemispherectomy based on a cadaver study with advanced 3D modeling provides a unique perspective on the anatomical intricacies of this procedure. Using advanced 3D modeling, the authors offer valuable insights into the endoscopic anatomy, facilitating better surgical planning and execution. Outcomes of endoscopic treatment for early correction of craniosynostosis in children present the benefits and results of early intervention for this congenital skull deformity. This chapter underscores timely surgical correction's importance in promoting normal brain development and growth. The chapter on autonomic dysreflexia with hypertension following durotomy-related intradural spread of irrigation fluid and air during routine spinal endoscopy addresses a severe but rare complication of spinal endoscopy. The authors discuss the pathophysiology, recognition, and management of autonomic dysreflexia to enhance patient safety. Finally, a commonly overlooked issue during thoracic spinal endoscopy is given credence in this volume's final chapter, highlighting the importance of preoperative identification of the Adamkiewicz System. A thorough preoperative workup is needed to avoid catastrophic complications during thoracic spinal endoscopy. By identifying Adamkiewicz's artery system, surgeons can better navigate the thoracic spine and reduce the risk of spinal cord ischemia.

Each chapter in this volume has been meticulously selected to reflect contemporary trends and innovations in neuroendoscopy of the brain, anterior and posterior fossa, brain stem, and

relevant interventional pain management procedures. By addressing the need for safer, more efficient, and cost-effective solutions, this book aims to meet the demands of patients, healthcare providers, and policymakers. The editors hope that Vol. 2 of Neuroendoscopy and Interventional Pain Medicine: Intra- and Extradural Endoscopy & Fetoscopy Techniques of the Brain and Neuroaxis serves as an indispensable resource for clinicians and researchers committed to advancing the field and improving patient care.

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CHAPTER 1

State-of-the-Art in Direct Endoscopic Visualization of the Brain and Neuroaxis

Ernesto Luis Carvallo Cruz[1], William Omar Contreras López[2,*], Kai-Uwe Lewandrowski[3,4,5], Stefan Landgraeber[6], Jorge Felipe Ramírez León[7,8,9], Peter Winkler[10], Benedikt Burkhardt[11] and **Joachim Oertel[12]**

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Abstract: Over the past two decades, the endoscopic endonasal approach has significantly expanded the armamentarium of minimally invasive skull base surgery. Initially developed for the treatment of pituitary adenomas, endoscopic endonasal skull base surgery (EESBS) has found increasing utility in managing a broad spectrum of skull base pathologies. Its application extends from the midline, encompassing the crista galli process to the occipitocervical junction, and laterally to the parasellar areas and petroclival apex. In recent years, there has been a notable shift from the exclusive use of endoscopic technology in endonasal pituitary surgery to other neuroendoscopic

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procedures. This chapter aims to provide the reader with an up-to-date overview of clinical trials on endoscopic neurosurgery of the skull base, brain, and neuroaxis. Through a comprehensive review of the state-of-the-art published peer-reviewed literature, the authors strive to offer a concise summary of the current concepts in this rapidly advancing field.

Keywords: Brain, Direct visualization, Endoscopic surgery, Neuroaxis, Skull base.

INTRODUCTION

Technological advancements have played a pivotal role in the expansion of endoscopic visualization in the field of brain and neuroaxis. This innovative tool has emerged as a transformative technique, granting neurosurgeons unparalleled access during surgical procedures. Direct endoscopic visualization necessitates specialized endoscopes equipped with high-definition cameras and illumination systems. When combined with three-dimensional imaging systems, these high-definition cameras offer neurosurgeons an immersive and highly detailed view of the surgical field. This superior visualization facilitates the identification of critical structures and improves spatial orientation. Moreover, this technique provides a minimally invasive alternative to traditional open surgery, mitigating the risks associated with extensive tissue disruption while enhancing surgical precision and patient outcomes.

The boundaries of transnasal endoscopic surgery in the pituitary fossa have been surpassed, and its applications now extend from the midline, spanning from the crista galli process to the occipitocervical junction. It extends laterally to the parasellar areas and petroclival apex in the posterior skull base. The ability to directly visualize pathological structures, assess lesion extent, and precisely target treatment sites has made neuroendoscopy a competitive alternative to traditional open surgery for treating brain tumors, vascular malformations, hydrocephalus, and other conditions affecting the brain and neuroaxis. Furthermore, the applications of endoscopic surgery extend beyond conventional neurosurgery, finding utility in diagnostic biopsies, intracranial pressure monitoring, and cerebrospinal fluid management.

The advantages of direct endoscopic visualization are manifold. By utilizing smaller incisions or natural orifices, this technique minimizes tissue trauma and reduces the risk of complications such as infection, bleeding, and scarring. Additionally, endoscopes' magnification and illumination capabilities enable surgeons to visualize structures with enhanced clarity and precision, thereby promoting optimal decision-making during surgery. Moreover, this technology contributes well to integrating augmented reality and virtual reality platforms,

further improving surgical planning and intraoperative navigation, thereby fostering safer and more efficient procedures. Furthermore, the minimally invasive nature of neuroendoscopy often results in shorter hospital stays, faster recovery times, and improved patient satisfaction. In this chapter, the authors aim to provide an up-to-date overview of clinical trials on endoscopic neurosurgery of the skull base, brain, and neuroaxis.

Historical Perspectives

Since the dawn of the 20th century, endoscopic neurosurgical modalities have evolved significantly. Hermann Schloffer initiated the transsphenoidal access in 1906, innovatively accessing a pituitary neoplasm via the sphenoid bone. L'Espinasse, in 1910, employed a cystoscope for choroid plexus fulguration in two infants, heralding success in one [1]. Walter Dandy's 1922 endeavor for a choroid plexectomy found no success [2]; however, 1923 saw Mixter's landmark achievement with an endoscopic third ventriculostomy (ETV) using a urethroscope on a pediatric patient [3]. Scarff later introduced a state-of-the-art endoscope in 1935, playing a pivotal role in addressing hydrocephalus arising from benign aqueductal stenosis or periaqueductal masses [1, 4].

The paradigm shifted with Nulsen and Spitz's introduction of ventricular cerebrospinal fluid (CSF) shunting in 1952 [5]. Nevertheless, 1959 marked the ushering in of modern endoscopy through the rod-lens system developed by Harold Hopkins. By 1963, Gerard Guiot made noteworthy strides with a fiberoptic endoscopic transnasal transsphenoidal intervention. Yet, the operating microscope retained its supremacy, especially in skull base surgeries [5].

With the emergence of coupled-charge devices from Bell Laboratories in 1969, video-endoscopy found its footing, and was subsequently honed by Karl Storz. The subsequent decade observed an ETV renaissance for obstructive hydrocephalus, propelled by enhanced endoscopic visualization. In 1978, Vries delineated the ETV's potential using cutting-edge fiberoptic instruments [6]. Thereafter, Jones *et al.* highlighted evolving shunt-free success trajectories, peaking at 61% in a pool of 103 patients by 1994 [7] [8], with contemporary rates oscillating between 80% to 95% [1, 4 - 8]. In a further pioneering leap, 1992 saw Roger Jankowski *et al.* reporting the first endonasal pituitary excision via endoscopy [9], followed by Ricardo Carrau and Hae-Dong Jho's substantial series in 1997, encompassing 50 patients [10].

The Standards

Neuroendoscopy has evolved to encompass a plethora of conditions beyond traditional ventricular interventions. Now, its application extends to address

CHAPTER 2

Trigeminal Tractotomies and Nucleotomies

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Abstract: Microendoscopic trigeminal nucleotractotomy (MENT) is a minimally invasive surgical procedure used to treat trigeminal neuralgia (TN). In this chapter, the authors describe the clinical outcomes associated with MENT regarding pain relief and functional improvement. Our novel technique resulted in a significant reduction in pain scores following MENT, as indicated by a decrease in the Visual Analog Scale (VAS) scores. Additionally, a substantial proportion of patients reported functional improvement, including enhanced ability to perform daily activities. The success of MENT is influenced by factors such as patient selection, surgical technique, and underlying causes of TN. Although the study provides short-term follow-up and feasibility data, further research with longer-term evaluations is necessary to assess the durability of pain relief achieved through MENT.

Keywords: Intractable pain, Microendoscopic, Trigeminal nucleotractotomy, Trigeminal neuralgia.

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INTRODUCTION

Trigeminal tractotomies and nucleotomies are surgical procedures performed to alleviate severe and intractable pain associated with trigeminal neuralgia, a debilitating condition characterized by sudden, intense facial pain. These procedures aim to disrupt or remove the nerve fibers involved in transmitting pain signals along the trigeminal nerve pathway. While both tractotomy and nucleotomy target the trigeminal nerve, they differ in their approaches and techniques.

Trigeminal tractotomy is a surgical procedure that involves the selective lesioning or cutting of specific nerve tracts within the trigeminal nerve. The goal is to interrupt the transmission of pain signals from the affected area to the brain, thereby providing pain relief. Tractotomy procedures can be performed through several approaches, including percutaneous techniques using radiofrequency ablation, glycerol injections, or balloon compression. More invasive approaches, such as microvascular decompression or stereotactic radiosurgery, may also be utilized.

A related procedure, trigeminal nucleotomy, is a surgical intervention that involves the partial or complete removal of a section of the trigeminal nerve nucleus, which is the central part of the trigeminal nerve within the brainstem. This procedure aims to directly interrupt the pain signals at their source by removing or damaging the nerve cells responsible for transmitting pain sensations. Trigeminal nucleotomy is typically performed using microsurgical techniques and requires a high level of precision to avoid damaging adjacent structures and minimize potential complications.

Both trigeminal tractotomy and nucleotomy have demonstrated effectiveness in providing pain relief for patients with severe trigeminal neuralgia. However, these procedures are considered last-resort options when other more conservative treatments, such as medications or nerve blocks, have failed to adequately control the pain. They are generally reserved for patients with severe, refractory pain who have exhausted all other treatment options.

While trigeminal tractotomies and nucleotomies can provide significant pain relief, they are not without potential risks and complications. Common complications associated with these procedures include sensory loss, facial numbness, weakness, infection, and cerebrospinal fluid leaks. The decision to undertake these procedures requires a thorough evaluation of the patient's individual circumstances, including the severity of pain, overall health, and potential risks and benefits. The use of image-guided navigation systems, intraoperative monitoring, and refined surgical approaches has enhanced precision

and reduced the risk of complications. Additionally, ongoing research aims to further optimize the selection criteria for these procedures and explore novel techniques, such as minimally invasive approaches and neurostimulation, to improve patient outcomes. In this chapter, the authors present the recent advances

in neurosurgical techniques and technologies, and their associated outcomes and safety profiles, with regard to trigeminal tractotomies and nucleotomies.

History

In 1937, Sjoqvist delineated an innovative approach wherein the trigeminal nerve's spinal tract could be meticulously sectioned *via* an incision on the posterolateral quadrant of the medulla, situated superiorly to the obex reference point [6]. Such an intervention typically culminated in ipsilateral thermoanalgesia confined to the facial region while preserving alternate sensation modalities [1]. Subsequent animal-based research and human surgical outcomes corroborated these preliminary findings. The technique gained traction, largely attributed to its reduced propensity to induce facial dysesthesias as compared to trigeminal rhizotomies [2]. Sjoqvist instituted this surgical strategy with the patient in a prone position, under the effect of general anesthesia. Following a suboccipital craniotomy, subsequent openings of the dura mater and arachnoid membrane were performed. The cerebellar tonsil was then gently retracted to afford optimal medullary visualization. The olive's anatomical prominence acted as the guiding landmark. Consequently, the trigeminal tract's incision was precisely executed a few millimeters posterior to the terminal vagal rootlet, to a depth range of 3.5–4 mm and situated 8–10 mm superior to the obex, in a domain enveloped by the restiform body (Fig. **1**).

The procedure was challenging and led to numerous complications, including ipsilateral ataxia, damage to the recurrent laryngeal nerve, lateropulsion, contralateral analgesia, vocal cord paralysis, gait anomalies, and limb postural sensibility issues. The most significant complications of the trigeminal tractotomy arose from injuries to the restiform body and the nucleus ambiguus. Later, Grant unintentionally created a lesion beneath Sjoqvist's suggested level, resulting in analgesia across all three ipsilateral branches of the trigeminal nerve. This discovery led him to conclude that making lesions further from Sjoqvist’s proposed area reduced complications. Thus, the lower part of the medulla and upper cervical cord emerged as the favored locations for trigeminal tractotomy, especially since cuts made at or below the obex could avoid damaging the spinocerebellar fibers.

CHAPTER 3

Endonasal Endoscopic Approaches to the Sellar Region and the Anterior Fossa

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Abstract: Endonasal endoscopic approaches have revolutionized surgical access to the sellar region and anterior fossa. These minimally invasive techniques utilize the natural nasal corridors to reach the target area, avoiding the need for external incisions. The endoscope provides excellent visualization and magnification, enabling precise surgical maneuvers. In this chapter, the authors describe the anatomical features for performing endoscopic endonasal approaches to the Sella and the anterior fossa. These approaches include the traditional endoscopic transsphenoidal approach to the Sella and extended endonasal approaches, including trans tuberculum, transplant, and transcribiform approaches. The most remarkable anatomical landmarks and surgical tenets are discussed. The anterior fossa houses critical structures like the anterior cranial base and the olfactory system. These structures can be approached for the resection of tumors, repair of cerebrospinal fluid leaks, and management of traumatic injuries. Endonasal endoscopic approaches offer reduced morbidity, shorter hospital stays, and faster recovery than traditional open approaches. Our clinical series shows that technological advancements and modern endoscopic surgical techniques further enhance the safety and efficacy of conventional transnasal methods, making them indispensable tools in the armamentarium of contemporary skull-base surgeons.

Keywords: Anterior fossa, Cribriform plate, Endonasal endoscopic, Endoscopic skull base surgery, Planum sphenoidale, Pituitary gland, Sellar region, Transsphenoidal, Tuberculum sellae.

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INTRODUCTION

Henry Schloffer described the first case of a transsphenoidal approach for resection of a hypophyseal tumor in 1907 [1]. Later, Harvey Cushing popularized this approach, modifying the original Schloffer technique [2, 3]. However, for decades mostly due to the limited light penetration in a narrow surgical corridor, Cushing's technique was replaced by complete transcranial procedures [4]. Guiot's introduction of the fluoroscope for intraoperative guidance, which was complemented by the use of the microscope by Hardy, contributed to the rebirth of this approach [5, 6]. Guiot also reported the first transsphenoidal surgery using an endoscope after endoscopic surgery was invented in the early 1800s [1]. In the mid-1960s, Storz, in collaboration with Hopkins, created the Storz-Hopkins endoscope, which contributed to the development of endoscopic technology. This new version brought optical improvements, better visualization, improved illumination, and provided a smaller and more flexible instrument [7]. One decade later, Apuzzo *et al.* [8], as well as Bushe and Halves [9] in Germany, began the description of combined microsurgical and endoscopic techniques for better visualization of skull base anatomical landmarks. Later, Jho and Carrau described their one-nasal fossa technique without using a nasal speculum, achieving a purely endonasal endoscopic approach (EEA) [10, 11]. Finally, during the late 1900s and early 2000s, new endoscopic schools began to appear, with several groups of neurosurgeons and otorhinolaryngologists investigating the surgical tenets, advantages, and limitations [12 - 17] of the technique. This chapter will focus on the anatomy and surgical features of the endoscopic endonasal approach (EEA) to the sella turcica and of its extended versions to the anterior skull base.

Endoscopic Endonasal Transsphenoidal Approach

Today, EEA represents the most widely used approach for sellar pathology. Most sellar and suprasellar tumors are accessed by opening the anterior aspect of the sella. Given the versatility of the endoscope and of endoscopic instruments, the manipulation of firm and soft tumors is feasible without the need to open the tuberculum sellae. If needed, the wide exposure of bony landmarks within the sphenoid sinus allows opening laterally to the anterior aspect of the cavernous sinus and the optic canal if going anteriorly. The traditional microscopic transsphenoidal approach was used for most pituitary adenomas for decades. Still, the advantages of the EEA, primarily improving magnification and visualization of critical structures and eliminating the need for brain retraction while minimizing manipulation of neurovascular structures, has promoted a trend towards minimally invasive endoscopic access [15, 18].

Endoscopic Anatomy & Surgical Technique

The wide intra-sphenoidal exposure begins with a straightforward approach from the nasal fossae. The nasal septum (pictured in the center of Fig. **1a**), the superior turbinate, and the choana are identified when entering the nares. At this point, the nasoseptal flap is normally harvested, if needed, for most of the extended approaches. A submucous transseptal approach is made. A resection of the vomer and the perpendicular plate of the ethmoid is performed. In some instances, these pieces of cartilage and bone are used to reconstruct the bony defect. Here, the sphenoid rostrum and keel are identified (Fig. **1b**) and drilled until the sphenoid sinus is opened. The intra-sphenoidal septum is resected. Then, the sella is observed, and the optic-carotid recesses (OCRs) are identified laterally on both sides (Fig. **1c**). Here, the anterior wall of the sella is drilled to expose the dura of the pituitary gland (Fig. **1d**). If needed, the bone is opened from the carotid protuberance of one side to the other. Most pituitary macroadenomas are resected through this approach, achieving a safe gross total resection (Fig. **2**).

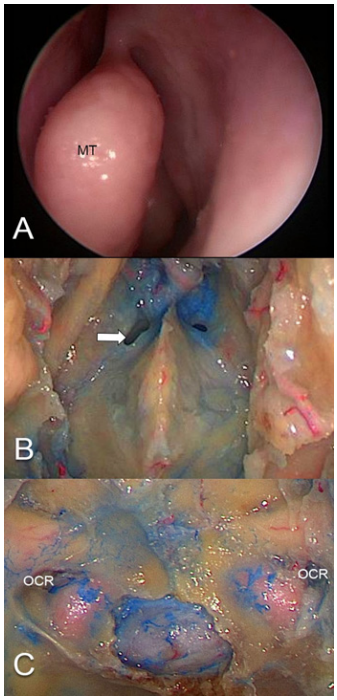

Fig. (1). Anatomy of the endoscopic endonasal approach. (**A**) The middle turbinate (MT) and the nasal septum are pictured. (**B**) The keel and the rostrum sphenoidale are observed, and the ostium of the right sphenoid sinus is marked with an arrow. (**C**) The sphenoid sinus is opened widely. The optic and the carotid protuberances are observed bilaterally. The optic-carotid recesses (OCR) are shown bilaterally.

CHAPTER 4

Pathophysiology of Myelomeningocele and Modern Surgical Treatment

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Abstract: Myelomeningocele (MMC) is the most relevant clinical variant of spina bifida - a birth defect resulting in an open vertebral column. The failure of the lumbosacral neural tube to close during embryonic development may compromise the spinal cord *in utero* due to exposure to amniotic fluid and irritation by the uterine wall. Resulting neurological deficits may vary depending on the spinal level involved. Most neural tube defects are diagnosed in the second trimester by ultrasound. Early prenatal diagnosis allows *in-utero* repair to diminish neurological deficits and the need for postnatal ventricular shunting. In this chapter, the authors present a brief review of the pathophysiology of fetal MMC and the various repair options, and their associated clinical outcomes. Clinical studies suggest improved short-term neurological outcomes with percutaneous minimally invasive and intrauterine fetoscopic techniques using endoscopes compared with an open prenatal or postnatal repair. The main limitations of these modern techniques are preterm premature rupture of membranes (PPROM) and

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dehiscence or leakage at the MMC repair. Additional benefits may include a lower risk of preterm labor, reduced need for postnatal revisions, and improved newborn maturity with higher gestational age. Fetoscopy may also offer better management of the membranes and primary closure of uterine port sites. The long-term cognitive, behavioral, and functional outcomes of fetoscopic MMC repair have yet to be determined. While cesarean section may be required for delivery in subsequent pregnancies after traditional open prenatal MMC repair to avoid uterine rupture, fetoscopic methods with externalization of the uterus by maternal laparotomy may allow spontaneous vaginal delivery at term.

Keywords: Fetoscopy, Lumbosacral neural tube, Myelomeningocele, Neurological deficits, Spina bifida.

INTRODUCTION

Spina bifida is a birth defect in which the vertebral column is open, commonly compromising the spinal cord. Myelomeningocele (MMC) is the most relevant clinical variant, which is characterized by the lumbosacral neural tube remaining open during embryonic development. *In-utero* exposure degenerates neural tissue, resulting in a neurological deficit that varies according to the level of injury. Prenatal diagnosis is achieved by ultrasound in the second trimester of pregnancy, allowing for a repair *in utero* to prevent neurological deficits. Fetal MMC repair has been associated with improved short-term neurological outcomes compared with postnatal repair. In recent years, these techniques have made it possible to reduce the neurological impact and the quality of life of the affected individuals. Currently, the establishment of a standardized surgical technique is being debated. These standards are beneficial to ensure the best results for patients and their families. This chapter aims to summarize the main aspects concerning the pathophysiology of myelomeningocele, its prenatal diagnosis, and the principal current therapeutic options.

Pathophysiology

Genetic and non-genetic factors contribute to neural tube defects [1]. The genetic risk has been estimated at 60-70% based on the relative rate of involvement in twins [2]. Less than 10% of neural tube defects are syndromic, with expressions of chromosomal disorders such as trisomy 13 or 18. The majority are non-syndromic and occur sporadically. Accumulating evidence in recent years has shown a model of multifactorial origin for nonsyndromic neural tube defects, which includes multiple genes and non-genetic factors [1]. The fact that the majority of fetuses and newborns affected with anencephaly are female suggests a sex-associated genetic factor or an epigenetic component in anencephaly [3].

Folate deficiency is one of the most important non-genetic MMC risk factors. Factors that escalate the probability of spina bifida are iterated in Table **1**.

Table 1. Risk factors for neural tube defects.

Maternal Nutritional Factors	Other Maternal Factors	Environmental Factors
Use of alcohol	Smoking	Air pollution
Use of caffeine	Hyperthermia in the first trimester	Disinfectant contaminants in drinking water
Low intake of folates	Low socioeconomic level	Components related to nitrates
High glycemic index	Maternal diseases and infections	Organic solvents
Low methionine intake	Insulin-dependent pregestational diabetes	Pesticides
Low AFP levels	Pre-gestational obesity	Polycyl aromatic hydrocarbons
Low serum levels of vitamin B12	Psychological stress	-
Low levels of vitamin C	Use of valproic acid	-
Low zinc levels	-	-

At the core of MMC pathophysiology lies an embryonic aberration wherein the neural tube in the spinal domain of the embryo remains unsealed. Such a defect culminates in the sustained exposure of the neural tube to the amniotic milieu [1]. Vertebrates undergo two distinct stages in the formation of the medullary canal; the primary neurulation and subsequent canalization. In Homo sapiens, the onset of primary neurulation is marked at the juncture between the prospective brain stem and cervical spine approximately 22 days subsequent to fertilization. From this nexus, there is a bidirectional closure of the neural tube, both cranially towards the brain stem and caudally towards the spine. By the 24^{th} gestational day, the cranial sealing culminates at the rostral neuropore. Contrarily, spinal closure persists over an extended period, methodically constituting the neuraxis until its termination at the caudal neuropore around the 26^{th} day, achieving closure proximate to the sacrum [1, 4].

Neural tube defects (NTD) can occur due to failure of any of the aforementioned processes and are typically open defects, due to failure of the neuronal folds at the level of the dorsal midline [1]. The most severe NTD is craniorachischisis, which is characterized by the combination of anencephaly (absence of the brain and cranial vault, without skin covering) with a contiguous bony defect of the spine (also without meninges or sac covering the neural tissue – rachischisis or myeloschisis). In the case of this defect, closure fails to initiate on day 22. If the embryo successfully initiates closure, but cranial neurulation subsequently fails,

CHAPTER 5

Fetoscopy Techniques for Myelomeningocele

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Abstract: Myelomeningocele (MMC) repair was traditionally performed postpartum. Developmental delay, neurological deficits, and the need for shunting are persistent problems associated with this type of repair. Alternative open prenatal repairs have been proposed. Clinical studies suggest improved short-term neurological outcomes with percutaneous minimally invasive and intrauterine fetoscopic techniques using endoscopes, when compared with an open prenatal or postnatal repair. In this chapter, the authors present the various currently practiced forms of percutaneous fetoscopic MMC repair. These are frequently carried out *via* externalization of the uterus through a maternal laparotomy. The primary limitations of these procedures are preterm premature rupture of membranes (PPROM) and dehiscence or leakage at the MMC repair. The authors also present their preferred three-layer repair technique and their clinical outcomes of a small case series performed to date. Their results suggest several benefits of the full percutaneous fetoscopic technique, including a lower risk of preterm

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labor, reduced need for postnatal revisions, and improved newborn maturity with higher gestational age. The authors conclude that fetoscopy may also offer better management of the membranes and primary closure of uterine port sites. The long-term cognitive, behavioral, and functional outcomes of fetoscopic MMC repair will need to be studied. Additional clinical outcome studies should show whether caesarean section may be required for delivery in subsequent pregnancies following the use of the fetoscopic technique to avoid uterine rupture that is commonplace after traditional open prenatal MMC repair. With the authors' technique, spontaneous vaginal delivery at term is feasible.

Keywords: Developmental delay, Intrauterine fetoscopic techniques, Myelomeningocele, Neurological deficits, Postpartum.

INTRODUCTION TO FETOSCOPY TECHNIQUES

In this chapter, the authors will describe their current fetoscopy techniques.

At present, two primary procedures are performed: 1) The pure percutaneous technique and 2) the fetoscopy technique with exposure of the uterus by laparotomy. Many leading centers are members of an international consortium - the Fetal Medicine Foundation (FMF) [1]. The first author is also a member, and his center in Barranquilla, Colombia, is accredited by FMF. It is led by Dr. Belford of Texas Children's Hospital - an internationally recognized pioneering center - and provides training based on time-tested credentialing standards; requiring neurosurgeons to be trained in endoscopy and minimally invasive spinal surgery to be accredited. In recent years, these techniques have advanced significantly and gained wider acceptance. While standard uniform treatment guidelines are lacking, several well-publicized techniques [2 - 6] do exist that the authors review as the cornerstones of their local fetal MMC repair program at the Clinica Foscal Internacional, Bucaramanga, and at the General Clinic del Norte, Barranquilla, Colombia.

Percutaneous full Endoscopic Technique

The two-layer closure with three or four ports was popularized by Dr. Denise Araújo Lapa (Pedreira) who currently coordinates the Fetal Therapy Group at Hospital Infantil Sabará and works at Albert Einstein Hospital, São Paulo, Brazil [7]. The established inclusion criteria are as follows:

- Localized neural tube defect at any level, provided the parents understand the severity of the defect and its clinical consequences,
- Gestational age at the time of surgery between 24-28.9 weeks,
- Presence of hindbrain hernia,
- No other major abnormalities, and

- A normal karyotype

Exclusion criteria include:

- Placenta previa,
- Alloimmunization,
- Multiple gestations,
- Positive HIV serology,
- Hepatitis B or C, and
- Maternal conditions that increase the risk of surgery or anesthesia such as diabetes or uncontrolled hypertension

Procedural Steps

Under general anesthesia, an ultrasound-guided amnio-infusion of 500 mL of warm saline is performed, followed by percutaneous insertion of four trocars according to the Seldinger technique using three 11 French vascular ports (Terumo, Tokyo, Japan) and one laparoscopic needle-tipped trocar employing a 5-mm balloon (Applied Medical, Rancho Santa Margarita, CA, USA). Subsequently, almost all of the amniotic fluid is removed from the uterine cavity, and a pressure-limited uterine CO_2 insufflation with a mean pressure of 14 mm Hg is performed. The typical intrauterine pressure ranges between 10 to 18 mmHg with a flow rate of 30 ml/min. Humidified CO_2 is used for the insufflation. The neurosurgical procedure involves the release of the neural placode and undermining the skin edges to allow its inline approximation. A bio-cellulose patch (Bionext, Paraná, Brazil) is placed over the defect without using sutures. In some cases, a bilateral fascial flap is raised and sutured in the midline with a 3-0 polyglycolic acid absorbable suture or with a simple continuous suture (STRATAFIXTM Spiral knotless Tissue Control Device, Ethicon, USA). If there is enough skin, it is closed over the patch with a single 2.0 monofilament, for example, a non-absorbable polypropylene stitch (Quill SRS, Angiotech, PA, USA). When skin approximation is impossible, a bilaminar skin substitute is secured (Integra Dermal Regeneration Stencil, Plainsboro, NJ, USA; or Nevelia Bi-Layer Matrix, Symatese Aesthetics, France). Two stitches are placed over the bio-cellulose patch and sutured to the skin edges using a 4-0 monofilament nylon suture. Large MMC defects can be successfully treated in utero by a full percutaneous fetoscopic technique preferring a bilaminar skin substitute over a biocellulose patch. Since February 2018, this group of authors have been using a CO_2 heating/humidification system (Insuflow, Lexion Medical, MN, USA).

CHAPTER 6

Microendoscopic Intradural Cordotomy for the Treatment of Cancer Pain

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Abstract: Spinal chordotomy is an alternative to analgesic opioid therapy, nerve blocks, and subcutaneous or intravenous techniques for cancer-induced pain. Patients with advanced metastatic disease require significant pain relief. Unfortunately, not all patients respond well to the standard therapies. For these patients, cordotomy offers a potential breakthrough. Cordotomy involves thermally disrupting the nociceptive pathways in the anterior spinothalamic tract to interrupt pain transmission from the spinal cord to the brain. The anterior spinothalamic tract is responsible for somatic pain sensations, touch, and temperature discrimination. This chapter presents an endoscopic-assisted percutaneous anterolateral radiofrequency intradural cordotomy technique. The entire procedure is done under direct endoscopic visualization of the cervical spinal cord. The authors provide an up-to-date summary of targeted minimally invasive pain intervention, which utilizes controlled electrical stimulation to confirm the physiological target. It is associated with less trauma to surrounding spinal tissue and lower risks due to vascular injury or adverse effects of intrathecal contrast.

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Keywords: Analgesic opioid therapy, Cordotomy, Metastatic disease, Nerve blocks, Spinal chordotomy.

INTRODUCTION

Cancer can elicit pain by invading or destroying neighboring tissues. Additionally, tumor growth may exert pressure on nerves, bones, or organs, leading to pain. Another contributing factor is the release of pain-inducing chemicals by the tumor. Such pain can be managed through non-invasive methods, including analgesics and optimized opioid therapy, and semi-invasive approaches, such as nerve blocks and subcutaneous, intravenous, or spinal infusion techniques [1]. However, not all patients experience satisfactory pain relief using these methods [2, 3]. For these individuals, Cordotomy represents a potentially transformative intervention. Cordotomy involves the selective disruption of nociceptive pathways in the anterior spinothalamic tract within the spinal cord, achieved through thermal techniques. This disruption effectively interrupts the transmission of pain signals.

The anterior spinothalamic tract plays a crucial role in transmitting somatic pain sensations, and facilitating touch and temperature discrimination. This study introduces an innovative technique called endoscopic-assisted percutaneous anterolateral radiofrequency cordotomy. With this approach, we aim to attain intradural endoscopic visualization of the cervical spinal cord through a percutaneous method. This allows for more precise targeting of the spinal region for anterolateral cordotomy. Importantly, this technique helps minimize the risk of unintended damage to spinal tissue or blood vessels, ensuring a safer and more accurate procedure.

Cordotomy Rationale

The quintessential insertion point for the electrode within the spinal cord is strategically located at the median juncture between the dentate ligament and the ventral root ingress zone. Leveraging endoscopic guidance obviates the excessive dependency on fluoroscopy, eliminating the necessity for intrathecal contrast deployment. Upon meticulous optimization of the neurophysiological target, a conventional radiofrequency methodology is employed for cordotomy. This modality efficaciously provides superior analgesia devoid of supplemental complications or cerebrospinal fluid extravasation. Preliminary forays utilizing this technique suggest that percutaneous endoscopic interventions offer considerable promise for precise spinal cord manipulation, thereby improving both procedural safety and efficacy. While the debate surrounding the one-needle versus two-needle technique persists, our group prefers the dual-needle modality, considering it the safer alternative (Fig. **1**).

The protocol is initiated with a lateral foray into the spinal canal at the C1-2 interstice, under the vigilant guidance of fluoroscopy. Post the successful breach into the cerebrospinal fluid (CSF) employing a guiding cannula (17-gauge needle), the endoscope is deployed, providing excellent visualization of the spinal cord and its contiguous architectures. Such endoscopic clarity proffers a highly detailed delineation of critical anatomical waypoints, inclusive of the spinal cord's pial surface, arachnoid membrane, dentate ligament, dorsal and ventral root ingress zones, and vasculature (Fig. **2**).

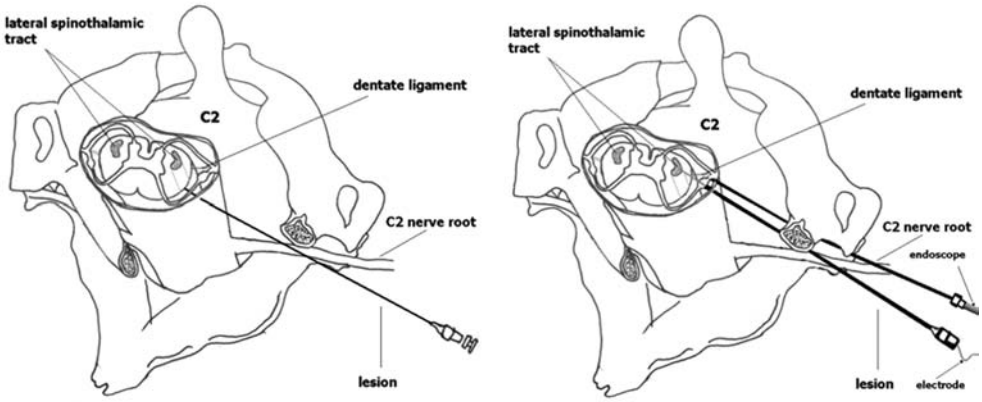

Fig. (1). Pictured; the (left) one puncture versus (right) two puncture techniques. The two ports technique allows for direct visualization of the RF electrode tip between the dentate ligament and the anterior spinal roots.

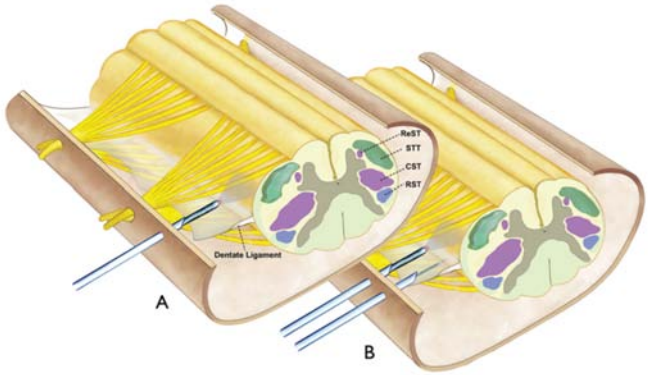

Fig. (2). Stepwise procedure for the microendoscopic cordotomy technique. Step 1: Insert the 17-gauge cannula perpendicular to the skin toward the spinal canal at the C1–2 interspace under fluoroscopic visualization. Step 2: Once the subarachnoid space is reached, the endoscope is introduced (A). Step 3: The second cannula is introduced in a parallel channel, also reaching the CSF space close to the first dural puncture (B). Step 4: Target identification followed by spinal cord puncture. Step 5: Stimulation and thermal RF lesion application, followed by intraoperative neurological examination (pinprick). CST = corticothalamic tract; ReST = reticulospinal tract; RST = rubrospinal tract. Copyright Erich Talamoni Fonoff. Published with permission. Figure is available in color online only. Neurosurg. 2016 Feb;124(2):389-96.

CHAPTER 7

Endoscopic Anatomy of the Transcallosal Hemispherotomy: A Cadaver Study With Advanced 3D Modeling

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Abstract: Transcallosal hemispherotomy is a surgical procedure used to treat severe epileptic seizures from a single brain hemisphere. This procedure involves the disconnection of the affected hemisphere from the rest of the brain, effectively preventing the spread of epileptic activity and reducing the frequency and severity of seizures. Endoscopic anatomy plays a crucial role in transcallosal hemispherectomy, as it allows for a minimally invasive approach. Using endoscopic techniques, surgeons can access and visualize the corpus callosum, a thick bundle of nerve fibers connecting the two cerebral hemispheres. This technique provides a clear view of the anatomical landmarks and enables precise disconnection of the affected hemisphere, while preserving critical neural structures. In this chapter, the authors review the endoscopic anatomy relevant to the transcallosal hemispherectomy identification of the corpus callosum's rostrum, genu, body, and splenium. By carefully navigating through these structures, surgeons can safely sever the connections between the affected and healthy hemispheres. This disconnection allows for better seizure control and improved quality of life for patients with severe epilepsy. The use of an endoscopic technique for transcallosal hemispherectomy may enable neurosurgeons to employ a minimally invasive approach to accomplish a precise disconnection of the affected hemisphere. It may thus form the basis for improved patient outcomes.

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Keywords: Anatomical landmarks, Endoscopic technique, Epileptic seizures, Transcallosal hemispherotomy.

INTRODUCTION

Hemispheric epileptic perturbations frequently culminate in calamitous seizure syndromes, predominantly manifesting in pediatric cohorts. In pediatric patients with refractory epilepsy, surgical intervention stands as a pivotal therapeutic avenue, yielding favorable results with judicious candidate selection [1 - 3]. Traditional disconnective modalities, like callosotomy, have conventionally been executed *via* expansive craniotomies utilizing microscopic guidance [4, 5]. These operative techniques, however, can engender complications; including augmented hemodynamic perturbations, intensified postsurgical discomfort, and concomitant protraction of hospitalization durations [6 - 8]. The refinement of microsurgical techniques [1, 4, 5] and improvements in instrumentation, imaging, robotics [9], and surgical image guidance systems [4, 10] facilitated the use of more minimally invasive approaches and surgical techniques in neurosurgery [11, 12]. These endoscopic techniques are gaining popularity as their application in functional neurosurgery has demonstrated that the endoscope can be used as a valuable tool to perform disconnective procedures in a minimally invasive fashion [11, 13]. While the surgical steps and clinical outcomes are similar to those used in microsurgical techniques, fewer complications have been noted [14, 15]. In this chapter, the authors undertake a detailed description of the intracerebral architecture, as approached through an endoscopic transcallosal conduit. To this end, they conducted a cadaveric examination of the pertinent surgical topography, providing a methodical exposition of the endoscopic transcallosal hemispherotomy procedure. Additionally, the authors present a 3D modeling analysis of the surgical anatomy to help the prospective endoscopic neurosurgeon better understand the complex anatomy of the endoscopic transcallosal hemispherotomy.

Historical Perspectives

In 1928, Dandy pioneered the anatomical hemispherectomy for addressing hemispheric epilepsy, specifically targeting infiltrating gliomas in the non-dominant hemisphere [16]. This groundbreaking surgical intervention entailed a comprehensive excision of a cerebral hemisphere inclusive of the basal ganglia, in conjunction with the severance of both the anterior and middle cerebral arteries post-bifurcation. The resultant surgical tableau revealed the corpus callosum, falx cerebri, tentorium, and the olfactory and optic nerves at the cranial base. A subsequent iteration by Gardner [17] retained the basal ganglia, cleaving the anterior and middle cerebral arteries subsequent to the genesis of the deep

perforators. This adaptation heralded enhanced postoperative motor prognoses concurrent with successful seizure management. McKenzie, in 1938, employed this procedure in a Canadian context for epilepsy treatment, specifically targeting infantile hemiplegia cases [18]. The adoption of the procedure continued to grow post-1950, epitomized by Krynauw's documentation of 12 pediatric epilepsy cases with concomitant behavioral alterations, which post-surgery exhibited promising seizure resolutions [19]. By 1952, Penfield and Rasmussen had implemented this methodology at the Montreal Neurological Institute [17, 20, 21].

While the anatomical hemispherectomy garnered widespread endorsement, it was not devoid of complications, notably including hydrocephalus [22, 23] and superficial cerebral hemosiderosis. Notwithstanding these challenges, the technique delivered impressive seizure cessation rates ranging between 43% and 90% [24]. Evolution in surgical practices led to the conceptualization of functional hemispherectomy and, subsequently, hemispherotomy; a paradigm initially posited by Olivier Delalande, which later bifurcated into two surgical trajectories: the vertical and peri-insular approaches championed by Delalande and Villemure, respectively [2, 3, 7, 23]. Both Delalande [25] and Villemure [23] proffered hemispherotomies necessitating expansive craniotomies compared to Schramm's approach, which emphasized a diminutive cortical excision, opting instead to functionally segregate the epileptic cortex from subcortical entities [26, 27]. This revised strategy yielded exemplary results, with 75%-90% of patients attaining a seizure-free state, as well as reduced morbidity rates [21]. Subsequent scholarly assessments focused on the merits of Schramm's technique, highlighting the limited craniotomy requisites, minimal cerebral parenchyma resection, diminished postoperative hydrocephalus risk, and lesser transfusion necessities [28]. Still, the perpetual pursuit for refined, patient-centric, minimally invasive modalities with concomitant reductions in blood loss and complications catalyzed the authors' elucidation of the endoscopic hemispherotomy technique, an exemplar of which is elaborated below.

Pre-dissection Planning and Quantitative Protocol

First, the authors set up the dissection limits of our functional disconnection. To this end, critical intracranial landmarks were selected, and the following were taken into account:

1. Genu of the corpus callosum, in its most anterior extreme,
2. Tentorium (tentorial apex),
3. Atrium of the lateral ventricle, in the glomus of the Choroid plexus,
4. Temporal ventricle horn

CHAPTER 8

Endoscopic Treatment for Early Correction of Craniosynostosis in Children

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Abstract: Initial treatments for craniosynostosis involved strip craniectomies, but due to unsatisfactory results in advanced stages, extensive cranial remodeling was introduced, despite its risks and prolonged hospital stays. Over the last 30 years, strip craniectomies have seen a revival, primarily due to the incorporation of minimally invasive endoscopic-assisted surgeries (EAS) as pioneered by Jiménez and Barone. EAS has shown marked advantages over older surgical methods, including shorter surgical times, reduced bleeding, and fewer hospitalization requirements, all while achieving comparable results in cranial deformity corrections. The most influential factor in perioperative morbidity is surgical time. EAS has emerged as a promising, effective treatment for craniosynostosis, suggesting its wider adoption in neurosurgical settings. Considering the relationship between age, surgical time, and blood loss, EAS may be suitably extended to children aged 6-12 months.

Keywords: Craniosynostosis, Endoscopic-assisted surgeries, Strip craniectomies.

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INTRODUCTION

Craniosynostosis represents a prevalent congenital craniofacial anomaly, stemming from the premature ossification and fusion of one or more cranial sutures [1, 2]. The ailment's classification spectrum ranges based on the suture involvement, delineating into simple or complex subtypes, and further categorized as primary or secondary forms [3]. Within the realm of primary craniosynostosis, distinctions arise between syndromic and non-syndromic variants, with the non-syndromic form being predominant [2 - 5]. Non-syndromic manifestations frequently include scaphocephaly, trigonocephaly, and anterior plagiocephaly presentations [2 - 6]. For their part, syndromic craniosynostosis commonly aligns with conditions such as Crouzon, Appert, Muenke, and Pfeiffer syndromes [3, 7 - 9]. This anomaly can result in a myriad of complications, encompassing craniofacial anomalies, sensory deficits, escalated intracranial pressure, and profound neurocognitive repercussions [2, 3, 9].

Historically, surgical interventions targeting craniosynostosis have evolved. Strip craniectomies once was the primary treatment, however, suboptimal outcomes precipitated their decline until a resurgence in the 1940s, emphasizing prophylactic and early interventions [10, 11]. Subsequent methodologies embraced expansive cranial reconstruction, albeit fraught with challenges such as elongated operative durations and significant hemorrhagic episodes [12 - 14]. A paradigm shift was observed in the 1990s with the advent of simplified endoscopic suturectomy, heralded as a novel approach [15]. This chapter describes the endoscopic-assisted surgery (EAS) juxtaposed against traditional open surgical methodologies in pediatric patients aged below 6 months. A synthesis of perioperative and reconstructive insights, derived from contemporary literature and bolstered by a rich 26-year institutional experience, will also be presented [16].

Open Surgical Technique

For all corrective interventions utilizing the Open Surgical Technique (OS), a standard procedural sequence is adhered to:

- **Incisions**: Ensuring the pericranium remains intact, strategic skin incisions are made. Notably, subperiosteal dissections are avoided.
- **Subgaleal Dissection**: A comprehensive subgaleal dissection is executed, interconnecting the separate incisions.
- **Dura Mater Dissection**: Utilizing Freer's dissector, a separation of the dura mater and the subjacent dural sinuses from the amalgamated sagittal suture is accomplished.

Condition-Specific Surgical Protocols:

Scaphocephaly (≤ 3 months):

- *Positioning*: The patient is oriented supinely, maintaining head neutrality and an inflected neck.
- *Incision*: A parasagittal "C" incision, originating from the coronal region and terminating at the lambda, is affected.
- *Sagittal Synostectomy*: A sagittal synostectomy spanning 4-5 cm is conducted.

Scaphocephaly (> 3 – 6 months):

- *Positioning*: The patient is positioned supinely in a semi-Fowler stance, ensuring head neutrality.
- *Incision*: A sinuous incision is made equidistant between the bregma and lambda, extending from one ear to the other (Fig. **1A**).
- *Burr Holes & Craniectomy*: Utilizing a craniotome, 4 trepanation portals are established – two retro bregmatic and two prelimbic, situated 2 cm away from the bilateral median. Following this, a 4-5 cm sagittal synostectomy and a subsequent craniectomy (measuring 1-2 cm) are performed.

Trigonocephaly:

- *Positioning*: With the head adjusted to a zero-degree inclination, the patient is positioned supinely.
- *Incision & Craniectomy*: A sinuous incision stretching between the ears is made, coinciding with the coronal territory (Fig. **1C**). A craniotome creates a burr hole over the stenotic metopic suture, which is elongated towards the anterior fontanelle. A metopic synostectomy of dimensions 2 cm x 3-4 cm is executed.

Anterior Plagiocephaly:

- *Positioning*: Patients are oriented supinely with their heads directed to the plagiocephaly's opposite side, revealing the affected frontotemporal region.
- *Incision & Craniectomy*: A coronal incision on the plagiocephalic side is rendered. Thereafter, a pair of trephination apertures are created, followed by a 2 cm wide retro coronal craniectomy.

CHAPTER 9

Autonomic Dysreflexia with Hypertension Following Durotomy-Related Intradural Spread of Irrigation Fluid and Air During Spinal Endoscopy

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Abstract: Trivialization of durotomy can cause complications for endoscopic spine surgeons when a patient's neurological or cardiovascular status unexpectedly deteriorates during or after surgery. The literature on fluid management strategies, irrigation-related risk factors, and clinical consequences of incidental durotomy during spinal endoscopy is limited. However, it suggests that most patients can be managed with supportive care without formal dural repair. There is currently no validated irrigation protocol for endoscopic spine surgery. In this chapter, the authors report severe complications in several patients, including the spread of irrigation fluid, blood, and air into the intradural and intracranial spaces. They concluded that patients should be informed about the risks associated with irrigated spinal endoscopy before surgery. Infrequent yet not insignificant, adversities encompassing intracranial hemorrhage, hydrocephalus, cephalalgia, cervical discomfort, convulsive events, and the perilous autonomic dysreflexia manifesting as hypertensive episodes can transpire should the irrigation fluid inadvertently enter the spinal cord or dural sac. Adept endoscopic spinal surgeons postulate an association between durotomy events and equilibration pressures associated with irrigation, a conjunction that, when amalgamated with copious irrigation volumes, may prove disconcerting. Further research is needed to determine whether specific thresholds for pressure, flow, and total volume of irrigation fluid

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should be established and to identify any additional risk factors beyond incidental durotomy or prolonged surgery time.

Keywords: Lumbar endoscopic surgery, Irrigation flow- and pressure, Adverse events and complications.

INTRODUCTION

The use of irrigation during spinal endoscopy in patients with incidental durotomy has been associated with anecdotal evidence of adverse events and complications. This minimally invasive surgical approach has gained popularity among a new generation of spine surgeons, who now incorporate endoscopic procedures into their training programs [1 - 4]. Key opinion leaders in the field stress the importance of mastering the learning curve to achieve good clinical outcomes [5]. Training and credentialing standards are still evolving, and there is an ongoing debate about who should perform these minimally invasive spine operations [1, 3, 6]. As the number of endoscopic spine surgeries increases, so does the awareness of potential pitfalls, pearls, and complications specific to these procedures [7 - 9].

The investigators in this study suspected that the rate of unrecognized durotomy could be higher than the previously reported 1% [9]. They observed rare but severe neurological and cardiovascular complications in endoscopic spine surgery patients and attributed them to durotomy [10, 11]. To investigate further, they conducted epidural pressure measurements and surveyed endoscopic spine surgeons regarding irrigation-related adverse events and complications [10].

During surgery, the clear irrigation fluid makes it difficult for the surgeon to assess its flow pattern and direction. Limited and indirect observations can be made, such as monitoring the quantity and direction of bleeding from epidural vessels or the movement of intrathecal rootlets within the semi-transparent nerve sac. Observing the flow patterns of blood leaking from small epidural vessels provides valuable information about the flow direction, similar to studying dye injectors in aero- or fluid-dynamics studies. Other signs can also be helpful, such as the direction and extent of rootlet herniations through an incidental durotomy or annular fibers through an annular tear.

The literature on fluid management and irrigation-related problems during lumbar spinal endoscopy is limited. Consequently, the authors report on profound complications within a concise cohort of patients, ascribed to the inadvertent intradural dispersion of irrigation fluid consequent to unanticipated durotomy. Additionally, they convey findings from intraoperative measurements of epidural pressures garnered at the locus of surgical decompression. Moreover, the authors

share the findings of a survey conducted among busy endoscopic spine surgeons, focusing on their usage patterns and perceived problems related to irrigation fluid. The authors aim to raise awareness among unsuspecting and novice endoscopic spine surgeons about the potential for sudden and unexpected declines in neurological and cardiovascular function, regardless of whether a durotomy is encountered when there is intradural spread of irrigation fluid.

Exemplary Problem Cases

The researchers observed durotomy-related complications during an irrigated spinal endoscopy in a 52-year-old female patient who underwent routine interlaminar C6/7 endoscopic decompression for persistent arm pain caused by disc herniation. Preoperative MRI scans indicated C6/7 posterolateral disc herniation with evident root compression. The surgery followed the technique described by Ruetten *et al.* (7-9), with the patient under general anesthesia and positioned prone. During the operation, controlling bleeding proved challenging, and a small 3-mm dural lesion was noted, possibly due to poor visualization caused by uncontrolled bleeding. The bleeding was successfully managed using bipolar coagulation, and dural repair was not deemed necessary following decompression (Figs. **1** and **2**).

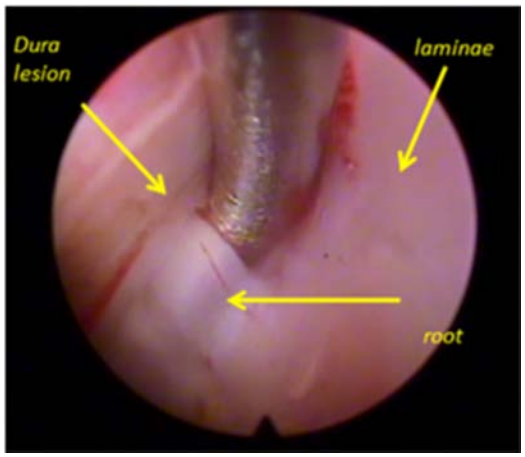

Fig. (1). In the illustrative case of a 52-year-old female who underwent a C6/7 disc herniation decompression *via* the interlaminar approach, fluid inadvertently permeated the intradural compartment through a minor unintentional durotomy. The hydrostatic pressure was augmented to enhance visual clarity. Following the procedure, the patient presented with diplopia and cephalalgia. Cranial computed tomography identified subarachnoid hemorrhage and hydrocephalus, consistent with Fischer Grade 4 subarachnoid bleeding.

After the surgery, the patient experienced postoperative symptoms, including neck pain, headache, and diplopia. Neurological examination revealed paresis of the right-sided lateral rectus muscle, suggesting abducens nerve paresis. Initially,

CHAPTER 10

Russian Roulette of Thoracic Spinal Endoscopy: The Importance of Preoperative Identification of Adamkiewicz System

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Abstract: Thoracic endoscopic spine surgery is gaining traction. During thoracic decompression, the arterial Adamkewicz system (AKA) can be encountered, with potentially severe implications if injured. This chapter outlines a diagnostic protocol and patient selection for the surgery based on a study examining surgical risks tied to the radicular magna artery. The authors share insights from fifteen patients with thoracic herniated discs and spinal stenosis who underwent preoperative CTA. This assessed the anatomical relationship of the Magna radicular artery to the surgical area. The Adamkiewicz artery's prevalent locations were T10/11 (15.4%), T11/12 (23.1%), and T9/10 (30.8%). Patients were grouped into three categories based on their pathology's proximity to the AKA foraminal entry. In five instances, the Magna radicular artery entered the spinal canal near the nerve root at the surgery site, prompting a surgical approach adjustment. The authors advocate for CTA evaluation to gauge surgical risks and adapt thoracic discectomy techniques based on the magna radicular artery's closeness to the pathology.

Keywords: Artery of Adamkiewicz, Spinal cord blood supply, Anterior spinal cord syndrome.

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INTRODUCTION

Thoracic endoscopic spine surgery is increasingly favored due to its minimally invasive characteristics and advantages over conventional methods such as laminectomy, costotransversectomy, and extracavitary interventions in the cervical and thoracic spine [1 - 3]. During thoracic procedures, whether open or endoscopic, segmental vessels, comprising arteries and veins, might be encountered, either traversing the disc space or appearing during decompression [4, 5]. When access to the herniated disc is challenging due to obstructions like the facet joint or rib head, vessel ligation might be an option [6]. This article's authors emphasize the importance of the arterial Adamkewicz system (AKA) in thoracic decompression and outline criteria for opting between contemporary, minimally invasive, encompassing endoscopic, and traditional surgical techniques [7].

The artery of Adamkiewicz, or Magna radicularis, displays variability in its positioning and trajectory within the thoracic spine [8]. While specialists are versed in the risks associated with standard thoracic interventions, the potential harm to the arterial network nourishing the thoracic spinal cord during endoscopy might be overlooked. Expertly executed spinal endoscopy can relieve pain from identified sources [9-15], but it's sometimes perceived as a basic operation not requiring specialized training [16, 17]. As a result, practitioners from diverse fields, like interventional radiology and pain management, undertake endoscopic decompressions with varied proficiency [18-24].

Underestimating the procedure, combined with its lower complications compared to open translaminar operations, might foster undue confidence [25]. However, compromising the Adamkiewicz system can yield grave outcomes, especially in settings like ambulatory centers without comprehensive support, leading to complications like paraplegia. In this manuscript, the authors detail their approach using the magna radicularis protocol for categorizing patients for thoracic disc procedures, either open or endoscopic. They discuss a retrospective analysis and their assessment framework for pinpointing the AKA's proximity to the surgical area before embarking on thoracic decompression.

Anatomical Variations

There are variations in the anatomical configuration of the AKA system. Typically, it originates from the left side of the aorta between the T8 and L2 levels, with the most common location being between T9 and T12. However, there have been reports of the AKA entering the spinal canal as low as the L2/3 level. The AKA was discovered incidentally after a patient experienced spinal cord infarction following a right-sided transforaminal epidural steroid injection

[25]. The authors recommended injecting at a lower position in the neuroforamen, just above the caudal pedicle, as a routine practice [25]. In approximately 15% of patients, the AKA is found at the T8 level, with a documented diameter ranging from 0.6 to 1.8 mm [7]. Other anatomical variations include the presence of more than one AKA or the AKA system arising from the right side of the aorta or outside the typical T8 through L2 range. Furthermore, the angle at which the AKA joins the anterior spinal artery system may vary [7]. In some cases, collateral circulation from the muscular, intercostal, or lumbar arteries may be present, especially if the AKA is occluded [25]. Injury to the AKA system can result in anterior spinal cord syndrome, characterized by motor deficits and typically preserved sensory function [26, 27]. Neurological damage may manifest as fecal and urinary incontinence.

AKA Identification

Computed tomography angiography (CTA) is recommended when assessing thoracoabdominal aortic aneurysm to pinpoint the AKA [28, 29]. In one instance, the authors identified its entry into the spinal canal at the planned thoracic surgical level in a patient (Fig. **1**) [28]. This finding led them to consistently employ CTA for those with thoracic disc herniation to avert potential neurological issues. When the surgical plan and the AKA's position align on the same side, there have been adjustments in surgical tactics, as documented in prior instances [30-33]. Differentiating the AKA from the anterior radiculomedullary vein is vital due to their parallel trajectories [34].

Fig. (1). Coronal computed Tomography (CT) angiography shows the entry foramen of the magna radicular artery and Adamkiewicz system.

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